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NEW COVER.

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SA 439	ARTICLES AND STATEMENTS ON C.D. IN MAGS, PERIODICALS PRESS ETC.
When papers require action by NOTER the word NOTE should be inserted in the box 1 2 3	"BENEATH THE CITY STREETS" - BOOK BY Mr Peter Laurie,

FILE NUMBER

DESTINATION	DATE	DESTINATION	DATE	DESTINATION	DATE
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cc Miss Marston
Mr Heaton
Mr Johnson
Mr Guy, F4
Mr McNamara, SHHD

CDA/74 43/28/3

Mr Morris

"BENEATH THE CITY STREETS" by PETER LAURIE

The Home Secretary may wish to be aware of the situation which has arisen in connection with the proposed publication of a new edition of this book.

2. The book, first published in 1970, contains a lot of information, much of it inaccurate, about government home defence plans. These, Mr Laurie implied, were sinister, being incapable of protecting civilians against hostile attack but intended to protect government against civil disorder. Before the first publication the publishers sent the manuscript to the Home Office, and other government departments were consulted about the possible disclosure of classified material. In the Home Office field, the book contained a list of the supposed locations of 25 government wartime headquarters, half of which were incorrect. The general conclusion reached was that Mr Laurie's speculations were unlikely to add to public knowledge of classified matters, and it was decided not to seek any alterations to the text, although the publishers were told that the Home Office could not accept any responsibility for the statements in the book.

3. Mr Laurie is now proposing to publish a revised edition, and sent a manuscript to the Secretary of the Defence Press and Broadcasting Committee (Admiral Farnhill). The new text contains a good deal of fresh material, particularly about confidential government communications. Admiral Farnhill warned Mr Laurie against publication (a copy of his letter dated 20 January is attached) and Mr Laurie then wrote to the Home Secretary, the S of S for Defence, the Attorney General and the Commissioner of Police saying that he could not avoid offending against the Official Secrets Act unless he had guidance as to the particular references which should be excluded from the book. The Ministry of Defence agreed to take the lead in dealing with this. Mr Laurie sent in a copy of those parts of his manuscript which he thinks might cause security problems, and this has been examined by the departments concerned.

4. The list of government wartime headquarters in the new manuscript is only marginally more accurate than that in the 1970 edition, but the prospect is that if unchecked successive editions would improve in accuracy. The full list of headquarters locations is classified "Confidential" and we have sought to have references to them excluded, but we do not think we should suggest any specific changes to the text.

5. Mr Laurie's new material appears to be a mixture of fact and conjecture, some of it obtained from published sources and some by direct observation of government installations. Individual items by themselves may be comparatively harmless but the book as a whole provides a collection of potentially damaging information of interest to hostile intelligence agencies which would otherwise take considerable effort to assemble.

6. Mr Laurie is an associate of Duncan Campbell who is awaiting trial, with Crispin Aubrey and John Berry, for offences against the Official Secrets Act including the publication of information about secret communications organisations. There is little doubt that some at least of the new material on this subject in Mr Laurie's manuscript is the product of his collaboration with Mr Campbell.

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Mr Laurie is known to want to help Mr Campbell, and in seeking to publish a new edition of his book he may have in mind:-

(a) that if he can claim Government approval of it, either explicitly or implicitly, the fact that it contains material on communications may help Mr Campbell's case;

(b) that he may be able to make capital out of his plight as an investigative journalist unable to obtain guidance about whether he is infringing the Official Secrets Act; and

(c) that publication around the time of the trial may help the sale of his book.

7. There can be no doubt that Mr Laurie's intention is to publish information about prohibited places, contrary to the Official Secrets Act, and that publication would be against the national interest. On the other hand, it is difficult to stop publication altogether since so much of Mr Laurie's material is either conjecture or has already been published, yet it is not possible to tell Mr Laurie which particular pieces of information should be excised from his book because to do so would confirm the accuracy of these.

8. It had been thought that Mr Laurie would not wish to put himself in the wrong by publishing before he has a reply from departments, and that by taking a reasonable time to examine his manuscript the likelihood that he could publish in time to affect Mr Campbell's trial would be diminished. Mr Laurie has, however, now written to the Ministry of Defence saying that his publishers, Granada Publications Ltd, having taken legal advice, are prepared to go ahead with the text more or less as it stands.

9. It is an offence under section 1 of the Official Secrets Act to collect and publish information which might be directly or indirectly useful to an enemy. It seems doubtful, however, whether Mr Laurie would in practice be convicted for publishing what has already appeared elsewhere or what he has deduced from personal observation especially since he has sought guidance at Ministerial level and offered to delete any specific items that offer a real threat to national security. Nevertheless it remains a matter of concern to avoid giving Mr Laurie any opportunity to claim that his manuscript has received official approval, lest that should affect the trial of Mr Aubrey, Mr Berry and Mr Campbell. The Ministry of Defence propose to write officially to Mr Laurie saying that for security reasons neither the Secretary of State for Defence nor any other Minister can confirm or deny the accuracy of his material or suggest specific amendments, but that there is no doubt that information of this sort would be of assistance to any enemy.

10. We think that what is proposed by the Ministry of Defence is the best that can be done. It is likely that the official letter will be sent before the end of the week.

L.

F6 Division
Queen Anne's Gate

19 April 1978

(39)

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Please quote
A78/152/RPE
Your reference
D/HQSy/13/8/11
Date
15 March 1978

Dear Hopkins

PETER LAURIE: BENEATH THE CITY STREETS

I have no comments to offer on the draft submission attached to your letter of 10 March to Law, save that I have suggested to you that consideration might in due course be given to a response to Laurie on the broad lines set out below. I mention this because it seems to me that in Laurie's argument, indicated in the final sentence of para 1 of the draft, there may be a fallacy. Namely that he "must" have or in some way is entitled to know specific details (as opposed to the pages containing the same), if it is contrary to the national interest for him to be supplied with that information.

(1) Mr Laurie has very properly submitted his manuscript for consideration of the material included, the publication of which might damage the interests of the State.

(2) In response he has been told the pages which contain such objectionable material. The pages in question are objectionable either because specific statements that are contained in them are objectionable per se on grounds of security or because they contain material which together with other material on another page or pages produce a cumulative effect which is similarly objectionable [assuming that this is a correct statement of the position].

(3) That response meets entirely the proper purpose to which his original submission is understood to have been directed.

(4) It would not be appropriate and indeed it would be wrong to identify the matters specifically and other than by reference to the page numbers - for the obvious reason.

(5) If Mr Laurie remains moved by the proper attitude which seems to have prompted his submission in the first place, he can be expected to accept this situation gracefully and as the proper price to be paid by any loyal citizen in avoiding damaging the national interest.

(6) For him to react otherwise would be unreasonable and would indicate a suspect attitude in his approach to the whole matter.

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(7) If he then proceeded to publish he must understand that he will stand a real risk of prosecution and he is to consider himself warned and on notice of that eventuality.

Of course if there does not exist in fact the subject matter for a likely prosecution in the event of Laurie publishing the lot, then the above could be an empty bluff and it could also be said perhaps that if the nature of the subject matter was not such that its publication demanded prosecution, its nature was not such that justified it being stifled.

I am copying this to the recipients of your letter.

Yours sincerely
R.P. Ellis

R P ELLIS

The Sunday Times Magazine, December 10, 1967

"Hide under the stairs when the bomb drops" They must be joking! But they're not

Report and photographs by Peter Laurie, montages by Richard Weigand

Peter Watkins' film The War Game could have been made any time these last 20 years. It is odd that at the moment he made clear to the taxpayer what nuclear war will feel like, the Government was making a deep and realistic reassessment of Civil Defence, our own deterrent was in eclipse and the Western world seemed further away from war than at any time since Hiroshima. Stimulated by these breaks in the nuclear overcast, The Sunday Times Magazine here offers what is probably the first complete review of our Civil Defence preparations. In gathering material we have had cautious, but generous help from the Home Office, several other Government departments and local authorities

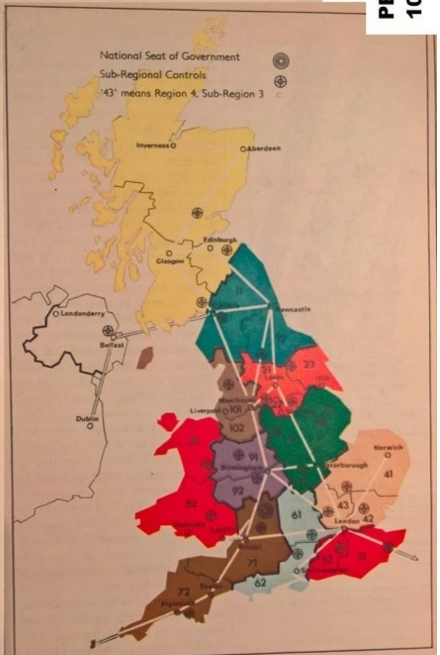
WRVS emergency cooks

The Central Electricity Generating Board has secret, reinforced regional control centres out in the country, ready to control the distribution of electric power after nuclear devastation. Fortunately, the biggest power stations (the grid and super grid) are also in the country and relatively immune. Electric power lines are duplicated everywhere

PETER LAURIE, CIVIL DEFENCE, THE SUNDAY TIMES MAGAZINE, 10 DECEMBER 1967

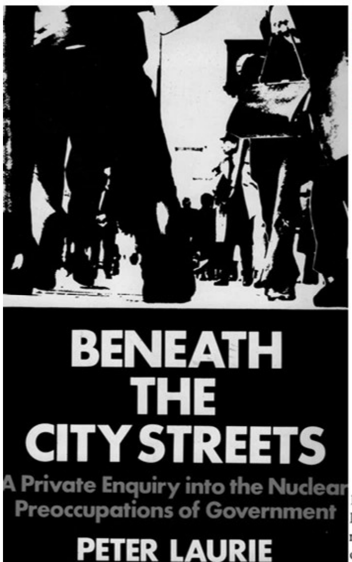
Refugees flying from the attacked cities would is one of their clothing depots - at Farnham, emergency cooking team at Watford; in the down the Ministry of Food has enough equipment

There are two reasonably likely attack patterns. The larger map shows a counter-city strike with five and one Megaton weapons: this could kill about nine million people (yellow circles show the 80 per cent. kill radius, red the severe to moderate blast damage). The smaller inset map shows an attack against air force bases and military installations

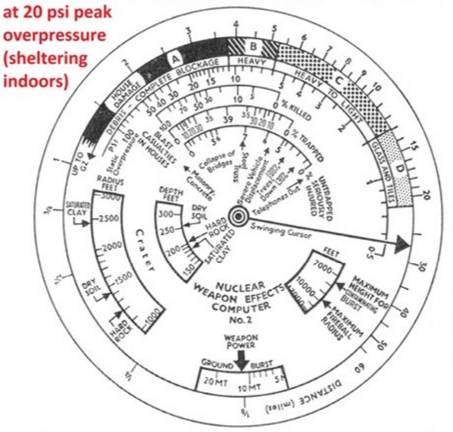


This map shows the nine English Civil Defence regions, which, with Northern Ireland, Scotland and Wales, form the basis for post-nuclear government. Each region has two or three sub-regions, each with a secret, fall-out-proof control. (The sites shown are linked by the G.P.O.'s microwave system, shown as white lines

Peter Laurie (b 1937), a Cambridge law and maths graduate, wrote an article on civil defence in the 10 December 1967 Sunday Times Magazine, then a book, Beneath the City Streets (1970) which gave a very accurate review of the science behind the UK Government's "controversial" nuclear blast casualties (data on the blast destruction of houses correlated to casualties in WW2 strikes) and no-firestorms (George Stanbury's analysis of the immense thermal shadowing of most windows by the skyline in cities) data, but followed that with a lot of nonsense about regional civil defence bunkers being used in a "Dr Strangelove" fantasy.



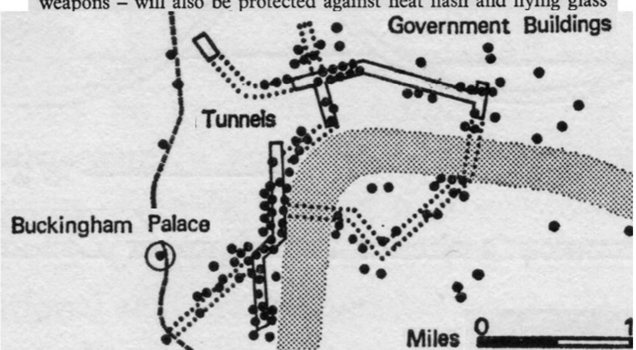
1963 UK Nuclear Weapon Effects Computer: 50% killed at 20 psi peak overpressure (sheltering indoors)



(Based on WWII indoor sheltering V2 attack data)

1. Civil defence officials are issued with weapons-effects calculators like this. Once the size of the weapon is set a great deal of information about the damage it causes at different ranges can be read off. (With acknowledgement to B R L Ltd).

The chances of people in such relatively fragile structures would seem to be small, but Second World War experience shows that they are surprisingly good. The main danger to people inside houses is collapse; but although the weapon that demolishes a house may vary enormously in size and range, the weight of a house remains the same, and in most cases the staircase is strong enough to support the debris that will fall on it. So people who shelter under the stairs – idiotic as this may sound for a precaution against nuclear weapons – will also be protected against heat flash and flying glass



NOTE: the following papers by Dr John McAulay, George Reginald Stanbury, and others of the UK Home Office Scientific Advisory Branch analyse nuclear weapons test data that has never been superseded for civil defence fallout decontamination of residential areas, sheltering, etc. The coordination of these activities was the purpose of the government's regional seats of government, contrary to Russian World Peace Council CND style propaganda against civil defence

British research material SHOULD BEEN PUBLISHED IN FULL TO DEBUNK THE RUSSIAN AND AMERICAN PROPAGANDA. Instead, the Laurie book led to enemy-style nonsense from Duncan Campbell in "War Plan UK"!

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Reviewed April 1988

Declassified J.C.

Home Office
Scientific Advisers' Branch

The Decontamination of Residential Areas

Dr. J. McAulay

Introduction

1. The work in progress at C.D.E.E., Porton, on radiological decontamination was discussed at the 28th Meeting of the Physics and Physical Chemistry Committee of the Chemical Defence Advisory Board, Ministry of Supply (Paper AC 14666 (Phys C. M28)).

2. The Committee asked for a paper giving the Home Office views and requirements for radiological decontamination. The present paper contains some background comments on the problems of decontaminating a built-up area from radioactive fall-out so that people may continue to live and work in that area without serious risk of radiation sickness.

3. The extent and timing of a decontamination operation will be governed largely by the nature and extent of the fall-out, by the available mechanised equipment for street scavenging, for high pressure water hosing or flushing and for earth moving in unpaved areas, and by the available number of people who can operate such equipment, by the dose of radiation which these workers will have already received or will get in transit and while doing the job, by the wartime emergency dose limit of 75r laid down for Civil Defence life saving operations and finally by the effort which can be expected from the resident population in doing manual work that cannot be done by the mechanised equipment.

4. One important factor independent of the above considerations is the effectiveness of appropriate decontamination procedures after single and repeated passes over typical surface areas. The surface to be cleaned will normally be an access route or a limited area in the midst of an extensively contaminated district.

5. The most useful measure of the effectiveness of a decontamination procedure would be the resulting percentage reduction in the gamma dose-rate at 3 ft. above ground level in the middle of the roadway or cleaned area.

6. It may be difficult to find a suitable site on which a radioactive simulant could be dispersed over a sufficiently large area to give percentage dose-rate reductions representative of wartime situations.

7. Much of the work in area decontamination trials may have to be done therefore with non-radioactive simulants. In this case the effectiveness of decontamination procedures may be measured in terms of either mass or number per cent of the particles removed from unit area of the surface. A rough estimate of the percentage dose-rate reduction in the middle of a street with various types of house on either side, can then be made from the geometry of the layout using the standard Points Scheme method developed in the Home Office for estimating the penetration of gamma radiation from fall-out into buildings (and enclosed spaces).

8. The general circumstances under which the decontamination of a residential area or of access routes to vital installations (gas, electricity, water pumping stations, telephones, hospitals etc.) would be required are described below. Some simplifying assumptions are also suggested to facilitate planning of large area decontamination trials.

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9. Finally, the latest available U.S. data on area decontamination have been extracted and reproduced in the Appendices to this paper. The data are of two types:-

(i) Assessment data taken from a joint services instruction manual and from an organisational study by the Stanford Research Institute

(ii) Experimental results from large scale trials on three different types of surface.

Fall-Out Zones

10. After a nuclear attack, the areas covered by fall-out will be divided into Zones W, X, Y and Z of increasing radiation intensity. A drill to be observed by the public in each of these zones had been prescribed.* This drill is designed to keep radiation sickness to a minimum and at the same time permit as many people as possible to undertake essential and rehabilitation duties which will involve some radiation exposure out of doors.

11. The outer boundaries of the W, X, Y and Z Zones have been defined as follows:-

W Zone - the limit of the area placed under a "Black" warning (fall-out imminent)

X Zone - the 0.3 r.p.h. contour at H + 48 hours (i.e. 48 hours after the bomb burst)

Y Zone - the 3 r.p.h. contour at H + 48 hours

Z Zone - the 10 r.p.h. contour at H + 48 hours

12. After hearing the "Black" warning people will have gone into their refuges where they must remain until they receive further instructions which may not happen for two to three days.

13. People near the outer boundary of the contaminated area will be told when the external dose-rate has fallen below 0.3 r.p.h. and thereafter they will be released from any further restriction of outdoor exposure (apart from the desirability of avoiding needless exposure).

Clearance of Z Zone

14. People in the Z zone who have had the benefit of good radiological protection in their refuges for at least 48 hours will survive and many, on the fringes of the zone, may escape radiation sickness if they can be removed to a clean area as soon as the external radioactivity has decayed sufficiently to permit entry into and transit from the contaminated area. The Y - Z boundary (10 r.p.h. at 48 hours) was chosen because this was considered to be the highest dose at which organised life could be maintained at D + 2 days onwards, not as the limit of radiological death or sickness. Z zone clearance areas have to be made as small as possible because of operational limitations.

Drills in the X and Y Zones

15. People in the X and Y Zones will have to continue living in their homes but they should escape serious risk of radiation sickness if they follow the

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*Manual of Civil Defence Vol. I. Pamphlet No. 2 Radioactive Fall-Out. Provisional Scheme of Public Control, H.M. Stationery Office, Price 1/3d.

prescribed drill limiting the time spent each day (a) out of the refuge room in other less protected parts of the house and (b) out of doors.

16. The daily drill prescribed for people living in the Y Zone is shown in Table 1 together with the cumulative doses they would receive in typical suburban houses with an average Protective Factor* of 10 and with a prepared refuge room on the ground floor or basement having a P.F. of 40.

Time after bomb burst	Daily Drill in the Y Zone	Cumulative Radiation doses in roentgens ø	
		outer edge	inner edge
2 days	Spent entirely in the refuge	20	70
2 days to 2 weeks	Not more than 2 hours outdoors		
	Not more than 8 hours indoors but not in refuge		
	At least 14 hours in refuge	50	170
2 weeks to 5 weeks	Not more than 4 hours out of doors	70	240
5 weeks to 1 year	Not more than 8 hours out of doors	-	-

17. A less exacting drill is prescribed for people in the X zone. After two entire days in the refuge, an outdoor exposure not exceeding 4 hours per day is allowed for the remainder of the first week and up to 8 hours per day for the next three months. The cumulative radiation dosages for the first three months to people in the X Zone should lie between 14 r (outer boundary) and 145r (inner boundary).

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*The Protective Factor is the ratio of the dose inside the refuge or the house to that on a large open space covered with the same radioactivity per unit area. In terraced houses and large blocks of buildings in the more closely built-up areas the Protective Factors are greater than those quoted for the more open suburbs of a City.

øThe cumulative doses have been calculated on the assumption that fission products decay in accordance with the formula $R_t = R_1 t^{-1.2}$ where R_t is the dose rate at any time "t" hours, and R_1 the dose rate at H + 1 hours. After three months the total dose should lie between 95r and 330r. Weathering, over such long periods in the U.K. is likely to remove some of the contamination and it would be unrealistic to quote cumulative dosages up to 1 year after the bomb burst.

Significance of daily periods out of doors

18. Some people living in the X and Y Zones will be required to maintain essential services e.g. medical, food distribution, water, gas, electricity and telephones; if they are not to be incapacitated by radiation sickness they must strictly observe the limits on outdoor exposure. As soon as the elementary needs of survival have been secured, other able-bodied people will be asked to help in the work of communal rehabilitation. Thus quite a large proportion of the residents in the X and Y Zones will have to travel to and from their appointed duties by the quickest means available. Furthermore someone from each home will have to go to a distribution centre at appointed intervals to collect food and other necessities for the family.

19. Of the total dose to which people living in the X and Y Zones would be subjected, about two thirds would be received during the two or four hour periods of permitted outdoor exposure each day. For example, in the typical suburban house already quoted (P.F. 10 in the house and 40 in the refuge), from the end of the second day to the end of the second week in the Y Zone;

64% of the total daily dose would be received during the 2 hour period out of doors

25% would be received in the 8 hours spent in the house but not in the refuge and

11% would be received during the 14 hours spent in the refuge.

Advantages of decontaminating access routes

20. From what has been said in the previous paragraphs, it is clear that the biggest benefit in reduction of the total dose to the population in the X and Y Zones would result from a significant reduction of the dose-rates on access routes from homes to distribution centres and to vital installations which have to be maintained.

21. The contributions to the gamma dose-rate in the middle of a street in a residential area will come from fall-out on the following surfaces:

(a) the roadway

(b) the pavements and paved access paths to and around houses

(c) gardens and other unpaved areas

(d) roofs of houses and outhouses

(e) more distant ground, or structures or trees etc. in the line of sight from the roadway.

In addition to the above there will be a certain amount of weaker gamma radiation scattered back from the atmosphere as "skyshine". The highest estimate is that it cannot exceed 18% on an open field and it may be only a few percent. It would be considerably less in a built-up area especially after the roadway and paved surfaces had been effectively decontaminated and it is suggested that, for present purposes, the "skyshine" contribution be ignored.

22. Since houses and buildings on either side of a street afford shielding from more distant sources of gamma radiation, major benefits in dose reduction could be achieved by effective removal of radioactive fall-out from the roadway and paved surfaces, especially if this can be done rapidly with mechanised sweeping and flushing equipment.

23. Important but lesser benefits (lesser because of the longer time and greater effort involved) would result from the decontamination of other surfaces in residential areas e.g. especially roofs, but also gardens and other unpaved open spaces. Work now in progress at C.D.E.E., Porton, will show to what extent fall-out particles of different shapes and sizes are likely to be reatined on various types of sloping roof surfaces. It is worth mentioning here that under conditions in which retention approached 100%, roughly half of the dose acquired by people inside a typical two-storey suburban house would come from fall-out retained on the roof. The use of an earth barrier three to four feet high (see Appendix B(ii)) would be of value where a large paved or unpaved area abuts on an access route. Similarly an earth barrier could be erected as a temporary shield near the perimeter of a large unpaved area until such time as arrangements could be made for the field to be ploughed without incurring excessive radiation exposure.

Effect of Type of Fall-Out

24. The type of fall-out will affect the effort needed to decontaminate access routes in a residential area. The fall-out may be typical of:

(a) a landburst in which the radioactivity is firmly fixed in the fall-out particles and there is no significant transfer of activity to the surface on which the fall-out is deposited even if the deposit is wetted by rainfall or is hosed or flushed away from the surface.

(b) an offshore and relatively deepwater burst in which large quantities of water and mud are lifted into the cloud so that the fall-out consists primarily of water droplets containing the radioactive fission products (or induced activity) in solution in colloidal suspension which can be transferred to the surface and be retained so tenaciously that the cost and effort of decontamination may be prohibitive.

25. Liquid droplet or "ionic" fall-out from an offshore waterburst would be much more localised and the radioactivity more intense than that from a landburst, leaving a much smaller fringe area in which decontamination might be of value compared with other remedial measures. It is the considered opinion of the Scientific Advisers' Branch that bursts of megaton weapons on British rivers such as the Clyde or the Thames would not raise enough water to produce fall-out differing significantly from that caused by a landburst and that water droplet fall-out with transferable activity would be infrequent compared with the landburst type of fall-out.

26. In view of the above considerations, the process of decontaminating a typical residential area will be primarily one of mechanical removal of the fall-out particles from the surfaces on which they have been deposited. They may be sucked or swept up into a container and removed to a safe dumping ground or they may be swept into the gutter and washed down into street drains or sumps. On some surfaces it may prove more effective to remove the bulk of the fall-out by dry sweeping or suction methods followed by flushing or fire hosing the surface to remove the remainder of the fall-out.

27. Results from a number of U.S. trial reports (see Appendices) indicate that mechanical clean up of roadways, even when the surface is rough concrete or macadam, is more than 90% effective whether the fall-out is dry or in slurry form, provided it is typical of a landburst.

Effect of Particle Shape and Size

28. Fall-out from a landburst will consist of fused, semi-fused and irregular-shaped particles in proportions which will vary with distance from ground zero and with the nature of the subsoil. It would be of interest to know whether the

removal of irregular particles from typical roadway and paved surfaces requires a significantly greater effort than the removal of fused rounded particles and whether a much greater effort is required to remove particles of 50 microns than to remove particles of 500 microns in diameter.

29. Fortunately a limit can be placed on the particle size range likely to be of importance in landbursts on the U.K. It is considered unnecessary in decontamination trials to use particles greater than 350 microns or less than 50 microns in diameter. The base of the stabilised cloud from a 1 M.T. groundburst weapon is about 44,000 ft. and a 50 micron particle would take over 15 hours to fall from this altitude and still longer for weapons of higher yield. The winds in the U.K., particularly in the levels below 45,000 ft. are very frequently higher than 15 m.p.h. (it has been stated that the frequency of these winds below 15 m.p.h. is about 12%) so that particles of 50 microns or less will be carried over 200 miles downwind or, in the case of wind shear, they will tend to be carried to the outer edges of the fall-out pattern (i.e. in the W zone and beyond) where the dose-rate is low and the need for decontamination is not such an urgent problem.

Surface Loading of Fall-Out Simulant in Area Decontamination Trials

30. Most of the trials with megaton weapons have taken place on coral islands and there is little reliable information on the relationship between the surface deposit of fall-out and the associated reference dose-rate contours, and none at all for megaton landbursts on clay or silicate soil. In one Pacific test the surface fall-out loadings at 8 miles and 60 miles downwind of ground zero of a 5 M.T. burst were estimated respectively at 4.5 and 0.06 gms. per square foot, but no systematic data are available.

31. In the large scale decontamination trials at Camp Stoneman in California in September, 1956, carriers impregnated with La 140 were used at a surface loading of 25 mgm. per square foot per r.p.h. at H + 1 hours, to simulate fall-out at 1000 to 10,000 r.p.h. at H + 1. It is probably easier to remove fall-out mechanically at the higher surface loadings and it is felt that the above figure is grossly excessive.

32. It is therefore suggested that in large scale area decontamination trials the surface deposit should be within the range of 0.05 to 5.0 gms, per square foot for simulating fall-out in the X and Y Zones.

33. It would be of interest to know whether the removal of fall-out at a surface loading of 0.05 gms. per square foot would require a significantly greater effort than at a surface loading of 5 gms. per square foot.

Scale of Decontamination Trials

34. Large scale decontamination trials are desirable on three typical roadway and paved surfaces such as:

(a) smooth concrete pavement

(b) asphalt - macadam (rough) surface

(c) rough concrete

It is suggested that the trials should be limited to the use of existing types of municipal road cleaning and firehosing equipment (possibly with modifications which would not impair the peacetime use of the equipment).

35. In order to get reliable estimates of the rates of clean up and the effort in manpower and materials it may be necessary to clean at least 100 ft. length and probably more of each type of road surface.

Secondary Factors which might be determined as a Laboratory Scale

36. As the large scale trials will involve a very considerable effort, many of the secondary factors might be studied on much smaller areas and probably on a laboratory scale and the optimum condition chosen in each case for the large scale trial. Secondary factors whose effects could be studied in this way are -

(a) Sharp irregular particles compared with rounded particles

(b) Particle size 50-350 microns

(c) Surface loading 0.05-5.0 gms. per square foot.

Miscellaneous Considerations

37. In the event of a nuclear war, so much of the country would be covered by fall-out that most communities would have to rely for some time on their own resources of men and equipment. The more the processes of decontamination can be mechanised the earlier it can be started and the greater the dose-saving benefits to the whole community. The work of decontaminating the X and Y Zones will be done by people who also live in the area and who will be subject to the same radiation field as the other residents. To avoid their incapacitation by radiation sickness is clearly desirable to provide them initially with much better than average shelter protection so that they will be able to carry out the work for a reasonable period before they acquire a dose of radiation comparable to that received by the other residents.

Review of American Studies on Area Decontamination

38. Extensive area decontamination trials have been carried out in the U.S.A. on paved, unpaved and roofing surfaces of a wide range of types. With few exceptions however (see Appendix B(iii) Table 5.7) the results reported are for landburst fall-out in which there is negligible transfer of activity to the surface even when the fall-out has formed a slurry with heavy rain or in the process of flushing it away from the surface.

The American evidence indicates that sweeping and pressure hosing procedures are effective, without excessive repetition, in removing some 90% of the fall-out even from rough macadam roads and from tar and gravel roofs. It is therefore important to confirm the American results with typical British equipment and on typical British road surfaces and on paved and roof surfaces, since both the conditions and the available equipment in the U.K. may differ considerably from those specified in the U.S. reports.

39. The American results have been extracted from two types of report and they are assembled together and reproduced in the corresponding Appendices.

A. Assessments in a Joint Services Manual and in a Civil Defence organisational report

(i) Radiological Recovery of Fixed Military Installations TM - 3 - 225 revised April 1958 (CD 11705)

(ii) Systems Analysis of Radiological Defence (November 1958). Prepared by the Stamford Research Institute, California for the U.S. Office of Civil and Defence Mobilisation.

B. Experimental Reports

(i) Radiological Warfare Agent Decontamination

Decontamination of Radioactive Ta - 182 dust from various roofing materials.

Reports CRLR 307 and 308 (July/August 1953)
(CD 11925 and CD 11926)

(ii) U.S.A.E.C. Report ITR 1464 (14/2/58)

Operation Plumbbob (Nevada, summer 1957)

Evaluation of Countermeasures System Components and Operational Procedures (CD 11605)

(iii) U.S. NRDL - TR - 196 (27.12.57)

Cost and Effectiveness of Decontamination Procedures for Land Targets (Test at Camp Stoneman, California, September 1956) (CD 12030)

Of the above only the last report contains some data on fall-out with transferable or ionic activity from an Off-shore water burst.

Appendix A (I)

Data extracted from Radiological Recovery of Fixed Military Installations

F.M.I. Sheet I

Performance of Common reclamation methods for paved areas and buildings

Surface of building or paved area	Standard dose-rate at 1 hour after burst	Residual Numbers for decontamination methods (1)		
		Firehosing or street flushing	Firehosing plus scrubbing	Hot liquid cleaning (2)
Asphaltic Concrete	300 1000 3000	0.07 0.03 0.01	0.05 0.02 0.008	0.02 0.01 0.004
Portland Cement Concrete	300 1000 3000	0.04 0.02 0.008	0.03 0.02 0.006	0.02 0.008 0.003
Tar and gravel roof	300 1000 3000	0.03 0.02 0.01	0.03 0.02 0.01	0.01 0.009 0.004
Composition roofing	300 1000 3000	0.04 0.03 0.01	0.04 0.02 0.01	0.02 0.01 0.005
Wood shingles (tiles)	300 1000 3000	0.17 0.10 0.04	0.13 0.08 0.03	0.06 0.04 0.01
Galvanised steel, corregated	300 1000 3000	0.05 0.02 0.006	0.04 0.01 0.005	0.02 0.006 0.002
Smooth painted surface	300 1000 3000	0.04 0.01 0.004	0.03 0.008 0.003	0.01 0.004 0.001

1. In this report the Residual Number is the fractional dose reduction in the centre of the area after the decontamination of the area plus a surrounding buffer zone of 600 feet width of paved or 200 feet of unpaved. Hence the Residual Number also represents the fraction of the radioactive contamination remaining on the surface.

2. Wet steam 105 psig 320°F (1500 lb/hr) and 1000 gal /hour water at 20 psig.

Appendix A(I)

F.M.I. Sheet 2

Notes on procedure and rates of operation

Paved areas and structures

1. Firehosing

The data relate to the clean up of a large area, the fall-out being pushed into a drainage channel at the far edges. The data on rates of operation are much less than would be the case for typical British streets with gutters and drains.

Equipment: Hydrant, booster pump, $2\frac{1}{2}$ inch hose, Y branch feeding two $1\frac{1}{2}$ inch hoses each delivering 100 gallons per minute at 80 p.s.i.g.

Operators: Four men per $1\frac{1}{2}$ inch hose.

Rate: Areas 7,500 sq. ft. per hour per nozzle.

Structures 2,000 sq. ft. per hour per nozzle.

2. Motorised flushing (for large areas only)

Equipment: Flusher delivering 800 gallons per minute at 90 p.s.i.g.

Operators: Two men.

Rate: 35,000 sq. ft. per hour.

3. Hot liquid cleaning

Equipment: Injector Unit, lance and nozzle, steam (1500 lb/hour unit at 105 p.s.i.g. and 320°F): Water (1000 gallons per hour at 20 p.s.i.g.) and Detergent.

Operators: Three men per lance.

Rate: Roofs 2500 sq. ft./hour

Walls 2000 sq. ft/hour.

Appendix A(i)

F.M.I. Sheet 3

Reclamation characteristics of various surfaces

Surface	Reclamation Characteristics
Composition shingles Prepared roll roofing Tar Paper	Similar to composition roofing
Corrugated sheet metal Steel Transite Glazed brick or tile Tin Copper	Similar to galvanised steel, corrugated
Unpainted wood Wood piles, piers and posts Gypsum or fibreboard Unglazed tile or brick	Similar to wood shingles (i.e. wooden tiles)
Dense brick Cinder or concrete block Adobe brick Semi-glazed roof tile Stone	Similar to Portland Cement, concrete
Slate Asbestos shingles or siding Concrete piles, piers or posts Stucco	Similar to Portland Cement, concrete

Appendix A(i)

F.M.I. Sheet 4

Performance of Common reclamation methods for unpaved land areas

Method	Residual Number [1] for single pass
Ploughing (8 to 10 inches depth)	0.15
Motor Grader scraping [2] (2 to 4 inches cut)	0.07
Motorised scraping [3] (2 to 6 inches cut)	0.15
Filling (to 6 inches depth)	0.15
Motorised scraping plus either ploughing or filling	0.02

(1) See note Sheet 1.

(2) Earth pushed by slanting blade into windrows which are removed from the site.

(3) Earth lifted into a bucket and dumped off site - higher R.N. due largely to spillage.

Appendix A(i)

F.M.I. Sheet 5

Unpaved Land

1. Ploughing

Three share plough drawn by 125 HP tractor

Rate 35,000 sq. ft. /hour

One operator per gang of ploughs.

2. Motor grader scraping (without time for removal of windrows)

Motor grader with 10 ft. blade.

Rate along a 16 ft. wide roadway one pass on each half of road.

4,000 linear ft. /hour or

64,000 square ft. /hour.

3. Motorised scraper and bulldozer

The scraper takes soil into a bucket and the rate depends on the distance to the dumping ground and on the roughness of the ground.

4. Filling to a depth of 6 inches

Motorised scraper and bulldozer or mechanical shovel and truck.

Rate 3,000 to 10,000 sq. ft. depending on length of haul and nature of soil.

Appendix A(i)

F.M.I. Sheet 6

LOGISTICS of Decontamination

Method	Equipment Required per 100,000 sq. ft.(1)	Manpower requirements per unit of equipment
Firehosing Areas	0.28 hoses	4 men
Firehosing structures	1.04 hoses	2 men
Motorised street flusher	0.06 flushers	2 men
Firehosing and hand scrubbing on paved areas	0.42 hoses 0.84 brushes detergents	4 men per hose 2 men for scrubbing
Firehosing and scrubbing on structures	1.04 hoses 2.08 brushes 2.08 shovels detergents	4 men per hose 2 men for scrubbing
Hot liquid cleaning of roofs	0.84 lances	4 men
Ploughing	0.06 tractor with plough	1 man
Motor grader scraping	0.033 motor graders	1 man
Motorised scraping	0.42 scrapers	1 man
Filling	0.42 scrapers	1 man
Bulldozing	0.25 dozers	1 man

(1) Based on 48 hours operation of equipment: numbers are also based on 100% efficiency and do not allow time for setup or rest periods. These factors may reduce the efficiency by 15 to 25%.

Appendix A(ii)

Stanford Research Institute Report

The S.R.I. study is based on the surface decontamination data taken from the Report on the Recovery of Fixed Military Installations, (Appendix A(i)) but the assessment and conclusions have particular reference to Civil Defence.

Three of the more important conclusions are quoted below:-

(a) Organised decontamination operations could be carried out most effectively by trained crews using street cleaning, earth moving and fire-fighting equipment. By combining such methods with spontaneous popular efforts, a reduction of 50 to 90% in subsequent exposure of inhabitants could be achieved.

(b) Decontamination operations would be limited by equipment and water supplies. With present equipment and techniques, only a small percentage of the population could effectively be used in organising decontamination efforts. One per cent of the population would require about twenty working hours to achieve a reduction of 40% in exposure of urban populations and about 200 working hours for an 80% reduction. Individual efforts by the population in spading yards (i.e. unpaved areas) could achieve an additional 10% reduction. Decontamination operations also would be limited by permissible crew exposures, which would restrict early decontamination efforts (less than two weeks after the blast) to areas of generally low fall-out.

(c) Decontamination programmes require the organisation and training of crews of men to operate facilities that are generally available. Unless such organisation and training are provided, the programmes cannot be carried out effectively when the need arises. Present theory and experimental data upon which to plan civil decontamination measures are very sketchy, and requirements for equipment and training are poorly specified.

Certain basic assumptions are made in the S.R.I. assessment of decontamination procedures. These are -

1. Decontamination crews will be staffed by not more than one person per 100 population.

2. Crew members may not receive a total dose of more than 100 roentgens during decontamination operations.

3. The protective factors (P.F's) of typical American houses and large buildings* and heavy equipment used for decontamination are -

houses	2	
large buildings	10	
equipment	2 to 5	(but 2 is used in the assessment tables attached)

The S.R.I. assessment expresses the effectiveness of a decontamination procedure in two ways, defined as:-

---

*American houses and buildings are framed with thin walls and seim-basements and they offer much less radiological shielding than typical British houses and buildings.

Performance Value (P.V.)

$$\text{P.V.} = \frac{(\text{Rate of coverage}) \times (\text{fractional reduction of radiation})}{\text{Crew exposure factor}}$$

(Note: the exposure factor is the inverse of the protective factor.)

The Performance Value thus relates the effectiveness of a decontamination procedure to its cost in crew exposure.

Decontamination Value (D.V.)

$$\text{D.V.} = \frac{(\text{P.V.}) \times (\text{Fraction of open field radiation penetrating a shelter})}{(\text{Above ground surface area per capita})}$$

In the above, the surface area per capita must be evaluated for each type of exposed surface e.g. roofs, pavements etc.

The Decontamination Value involves assumptions about factors which might be different under British conditions and a complicated set of tabular data on penetration of radiation into buildings (in Appendix E of the report on the Recovery of Fixed Military Installations) is used in calculating the fraction of the open field radiation penetrating into shelters in houses and large buildings. Hence the Decontamination Value is a complex relation between the dose-rate reduction for a shelter inhabitant and the dose absorbed per capita in decontaminating an area but it indicates the relative importance of different procedures for the decontamination of specific types of area in residential and commercial sections of cities.

S.R.I. Sheet I shows the Performance Values and various other quantity and rate factors for various decontamination procedures. It will be noted that mechanised methods, by virtue of their high rates of coverage and operator protection, appear greatly superior to other methods. Time schedules are not considered in evaluating Performance Values because these needs are closely related to crew exposure restrictions.

S.R.I. Sheet 2 shows the distribution of various types of surface in the residential and commercial sections of an average American City expressed as square feet per head of the population. It shows also the fraction of the total external (open field) dose which penetrates into shelters in houses and large buildings in accordance with the assumed P.F. of 2 for dwelling houses and 10 for large buildings.

S.R.I. Sheet 3 shows the Decontamination Values for procedures in residential and commercial areas and the petrol and water requirements and working hours, all expressed as per capita, to decontaminate all areas of a city.

In this connection the outstanding value of cleaning streets by motorised sweeping (D.V. = 19) or water flushing (D.V. = 12) and removing the contaminated surface from unpaved areas by motor grading (D.V. = 16) compared with hand spading (D.V. = 0.013).

Appendix A(ii)

S.R.I. Sheet 1

Performance Value of Decontamination Measures

(Assuming crew exposure factor of 0.5 i.e. P.F. = 2)

(Data in U.S. gals. = 0.83 British gals.)

Decontamination Measure	Supply needs (per 1000 sq.ft.)	Rate of Coverage sq.ft/man-hr.	Fraction of Radiation Removed	Performance Value (see script)
Roofs				
Firehosing	0.4 gal gas 200 water	1,000	0.9	1,800
Firehosing and scrubbing	0.7 gal gas 1500 water	300	0.93	560
Firehosing and detergent scrubbing	same plus 2 lb detergent	300	0.97	580
Vacuum cleaning	Electricity	-	0.80	-
Paved Areas				
Firehosing	0.15 gal gas 700 water	2,000	0.96	3,800
Firehosing and scrub	0.2 " " 700 water	900	0.97	1,700
Firehosing and detergent scrub	same plus 2 lb detergent	900	0.98	1,800
Motorised flushing	0.3 gal gas 500 water	15,000	0.98	73,000
Motorised sweeping	0.1 gal gas	25,000	0.90	110,000
Unpaved Areas				
Power scraping or bull-dozing	0.5 gal gas	5,000	0.85	21,000
Motor grading	0.2 gal gas	25,000	0.85	110,000
Gang ploughing	0.2 gal gas	20,000	0.85	85,000
Spading (hand)		50	0.85	85
Obstructions (trees, fences etc.)				
Firehosing	0.4 gal gas 2000 water	1,000	0.8	1,600
Firehosing and scrubbing	0.7 gal gas 2500 water	300	0.9	540
Outside Walls				
Firehosing	0.3 gal gas 1300 water	1,500	0.97	2,900
Firehosing and scrub	0.4 gal gas 900 water	500	0.98	980
Firehosing and detergent scrub	same plus 4 lb detergent	500	0.99	990
Vacuum cleaning	Electricity	-	0.97	-

Appendix A(ii)

S.R.I. Sheet 2

Distribution of surface area types in a typical American City and their radiation contributions inside shelters

Type of Surface	Shelter in: Dwelling houses PF = 2 — Surface Area sq. ft. per capita	Shelter in: Dwelling houses PF = 2 — Fraction of the total external radiation penetrating into the shelter from the specified surfaces	Shelter in: Commercial Areas Large buildings PF = 10 — Surface Area sq. ft. per capita	Shelter in: Commercial Areas Large buildings PF = 10 — Fraction of the total external radiation penetrating into the shelter from the specified surfaces
Roofs	300	0.15	150	0.060
Streets	350	0.06	150	0.005
Other paved areas	300	0.10	150	0.010
Unpaved areas	1,000	0.15	300	0.014
Obstructions (fences, trees, etc.)	400	0.02	100	0.001
Outside Walls	400	0.02	200	0.010
Total exposure as fraction of external		0.50		0.100

Appendix A(ii)

S.R.I. Sheet 3

Decontamination Values for dwelling houses (residential areas) and large buildings (commercial areas). Crew exposure factor 0.5 (i.e. P.F.= 2)

Decontamination Measure	Decontamination Value		Hours work per capita to decontaminate		Fraction of radiation removed from the surface	Supply needs per capita to decontaminate all City areas (U.S. gals = 0.83 British gals.
	Houses (residential)	Large Buildings (commercial)	Houses (residential)	Large Buildings (commercial)		
Roofs						
300 sq. ft. residential 1500 sq. ft. commercial						
Firehosing	0.90	0.72	0.30	0.15	0.90	0.2 gals gas 900 gal water
Firehosing and detergent scrubbing	029	0.23	1.0	0.5	0.97	0.3 gals gas 700 gal water 3lb detergent
Streets						
350 sq. ft. residential 150 sq. ft. commercial						
Firehosing	0.65	0.11	0.18	0.08	0.96	0.08 gal gas 350 gal water
Motorised flushing	12.0	2.2	0.023	0.01	0.98	0.15 " " 250 " "
Motorised sweeping	19.0	3.1	0.014	0.006	0.90	0.05 " "
Other paved areas						
300 sq. ft. residential 150 sq. ft commercial						
Firehosing	1.1	0.27	0.15	0.08	0.96	0.07 gal gas 300 gal water
Unpaved areas						
1000 sq. ft. residential 300 sq ft. commercial						
Power scraping or bulldozing	3.6	1.0	0.2	0.06	0.85	0.7 gal gas
Motor grading	16.0	5.5	0.04	0.01	0.85	0.3 " "
Gang ploughing	13.0	4.2	0.05	0.015	0.85	0.3 " "
Spading (by hand)	0.013	0.004	20.0	6.0	0.85	-
Obstructions						
400 sq. ft. residential 100 sq. ft. commercial						
Firehosing	0.080	0.016	0.4	0.1	0.80	0.2 gal gas 1000 gal water
Firehosing and scrubbing	0.027	0.005	1.3	0.3	0.90	0.4 " " 1300 " "
Outside Walls						
400 sq. ft. residential 200 sq. ft. commercial						
Firehosing	0.15	0.15	0.27	0.13	0.17	0.2 gal gas 800 gal water
Firehosing and detergent scrubbing	0.05	0.05	0.8	0.4	0.99	0.2 " " 600 " " 2lb detergent

Appendix B(i)

U.S. Studies on the decontamination of representative roofing materials (Reports CRLR 307 and 308)

Panels, 4 ft. x 4 ft. sloped at an angle of 15 degrees except for the built-up tar and gravel roofs which had a slope of 2 degrees, were each contaminated with 210 mgs of a "dust" of Tantalum 182 irradiated to about 5 mc/gm. (Half life 117 days, 1.22 Mev gamma, particle size distribution not available).

The general conclusions were that if water hosing is used at least 40 psig is needed to achieve 90% removal of the contamination.

Vacuum cleaning was also very effective on rough surfaces but it took about three times as long as high pressure hosing.

On smooth surfaces weathering (a 5 to 7 m.p.h. wind) removed 60% of the activity in one day and the wind and rain removed 90% in forty-seven days. Rough surfaces showed 30 to 40% removal of activity by weathering after seven weeks.

The results are shown in R.P. Sheet I and it is to be noted that the roofing materials used are in no way typical of British materials.

Appendix B(i)

R. P. Sheet I (Roof Panels)

Decontamination Method	Surface Material	Total Time Minutes unless stated	Total water gallons	% Decontamination
Low pressure hosing 8 p s i g	Rolled asphalt	2	10	98
	strip shingle	4	20	84
	corrugated metal	2	10	95
	built-up tar and gravel	4	20	23
Low pressure hosing and brushing	r. a.	2	10	96
	s. s.	3	15	88
	c. m.	1	5	98
	t. and g.	4	20	44
Hosing 24 p s i g	t. and g.	45 sec.	6.5	32
Firehosing 40 p s i g	t. and g.	60 sec.	12.5	98
High pressure hosing 50 p s i g	r. a.	15 sec.	3.5	88
	s. s.	30 sec.	7.0	96
	c. m.	15 sec.	3.5	100
	t. and g.	60 sec.	14	95
H. P. hot water and steam (Seller's Unit) 90 p s i g hot water 8.3 gpm.	r. a.	30 sec.	4.2	94
	s. s.	1 min.	8.4	69
	c. m.	30 sec.	4.2	97
	t. and g.	1 min.	8.4	91
Vacuum cleaning	r. a.	2.5		99
	s. s.	2.5		91
	c.m.	1.5		97
	t. and g.	2.5		98
Dry sweeping	r. a.	2		82
	s. s.	2		0.9
	c. m.	2		96
	t. and g.	2		12

Appendix B(ii)

Plumb Bob Trial on Unpaved Ground

In this trial an area about 1 mile from ground zero of a tower burst bomb was contaminated to a peak intensity of about 60 r.p.h. A square 500 ft. by 500 ft. was monitored by recorders who came out of a nearby underground shelter and it was decontaminated starting at about H + 48 hours by a team of men with equipment brought from outside the contaminated area. It was again monitored after decontamination.

The ground consisted of stony desert from which boulders and larger stones had been scraped before the trial. It therefore represented the most difficult type of unpaved surface to clean by earth moving techniques.

Equipment used

4 motor graders (2 inch cut)
2 motorised scrapers
1 bulldozer

Procedure A 40' x 40' square was first cleared by the motor graders: this was enlarged to 60' x 60' by a 10' pass all round (pushing windrows to the periphery) and finally extended to 100' x 100'. Several trips with the scrapers were necessary to remove the windrows.

Finally a 200' wide buffer zone was cleared around the 100' x 100' area making a total cleared area of 500' x 500'.

Another 100' x 100' area was cleared in the same way but a 3' high earth barrier was built up round its periphery instead of the buffer zone.

The results of the decontamination are shown below in terms of the percentage residual dose-rate at the centre of the square.

Area cleared	Average % residual dose-rate at centre of the cleared square
40' x 40'	39
60' x 60'	32
100' x 100'	24
500' x 500'	16
After second pass over central 100' x 100' area	11
Centre of 100' x 100' Area with 3 ft. high earth barrier around it.	16

/Duration

Duration of task of clearing 500' x 500' area - 3 hours

Average Protective Factor of operators of the equipment - 5

(from doses recorded on their film badges.)

Appendix B(iii)

Camp Stoneman Trials September 1956

The large deserted Military Camp Stoneman was used for this trial Large areas of paved ground with different types of surface and huts with different types of roofing material were contaminated to an extent which was estimated to correspond to 1000 and 10,000 r.p.h. at H + 1 hours.

For this purpose a surface loading of fall-out simulant of 25 mg per sq. ft. per 1 r.p.h. at H + 1 i.e. 25 gms/sq. ft. to represent 100 r.p.h. and 250 gms/sq.ft. to represent 10,000 r.p.h. at H + 1 were chosen. It was later considered that this was much too heavy a contamination and the results were interpolated to 3000 r.p.h. at H + 1 but it was felt that they could not be extrapolated down to 300 r.p.h. at H + 1 without serious misgivings.

Two types of fall-out simulant were used, a dry powder and a slurry but both were in fact typical only of a landburst weapon as there was no transfer of radioactivity from the carrier particles into the solution or on to the surface contaminated.

The fall-out simulants were based on a solution of Lanthanum - 140 (half life 40.2 hours, 1.2 Mev gamma emission) which was mixed with the appropriate carrier material. The powdered simulant consisted of Camp Stoneman loam soil (40,000 lb used) impregnated with the La 140 solution: The slurry (30,000 lbs) was produced by impregnating dried harbour mud from San Francisco bay with the La - 140 solution and then adding an equal weight of water.

The results of various decontamination procedures on different types of surface in terms of effectiveness, rate of operation and man-hours effort are shown in Tables 5.1 to 5.6 reproduced from Report U.S. NRDL - TR- 196. The planning rates and effort include time required to set up the equipment and to move it from area to area and also include an adjustment for an estimated 75% efficiency in the productive effort.

Table 5.7 is also included: it contains data estimated on a similar basis for transferable or ionic fall-out from an off-shore water burst. The data in Table 5.7 have been estimated from laboratory experiments and some very limited data from two water burst trials.

Appendix B(iii)

Camp - Stoneman Trials

Table 5.1 Expected Recovery Performance on Asphaltic Concrete Exposed to Dry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of men	Effort[c]	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	8-16	.01	35	2	0.06	18-32	.006-.01	35	2	0.06
Firehosing	1-100[d]	.04	15	6-8	0.4-0.5	16-94[d]	.02	15	6-8	0.4-0.5
FH-HSD-FH[a]	12-19	.01-.02	10	11-13	1.1-1.3	26-38	.01	10	11-13	1.1-1.3

Table 5.2 Expected Recovery Performance on Portland Cement Concrete Exposed to Dry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effec- tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	6-12[e]	.01	35	2	0.06	8-27	.003-.009	35	2	0.06
Firehosing	19-34	.02-.03	15	6-8	0.4-0.5	18-35	.006-.01	15	6-8	0.4-0.5
FH-HSD-FH[a]	6-11	.01	10	11-13	1.1-1.3	9-14	.003-.005	10	11-13	1.1-1.3

[a]Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b]Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate:

[c]Effort, in man hr/1000 ft^2, results from dividing the number of men involved by the planning rate: $\frac{\text{column 4}}{\text{column 3}}$

[d]Poor specific activity data provided an extremely large confidence interval.

[e]This data from MF-MS-MF test results, and it is assumed that the MS operation did not add to the decontamination effectiveness.

Appendix B(iii)

Camp - Stoneman Trials

Table 5.3 Expected Recovery Performance on Asphaltic Concrete Exposed to Slurry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Motorized Flushing	44-58	.05	28	2	0.07	47-57	.02	28	2	0.07
Firehosing	24-70	.03-.07	9	6-8	0.7-0.9	50-74	.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	34-41	.04	9	11-13	1.2-1.4	36-42	.01	9	11-13	1.2-1.4

Table 5.4 Expected Recovery Performance on Portland Cement Concrete Exposed to Slurry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Motorized Flushing	35-52	.04	28	2	0.07	43-56	.01-.02	28	2	0.07
Firehosing	36-55[d]	.04	9	6-8	0.7-0.9	36-55[e]	.01-.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	8-62[d]	.01-.06	9	11-13	1.2-1.4	8-62[e]	.003-.02	9	11-13	1.2-1.4

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate:

[c] Effort, in man hr/1000 ft^2, results from dividing the number of men involved by the planning rate: $\frac{\text{column 4}}{\text{column 3}}$

[d] Inconsistent results provided the wide range.

[e] The range was expanded and adjusted to equal the width and magnitude of the 1000 r/hr values.

Appendix B(iii)

Camp Stoneman Trial

Table 5.5 Expected Recovery Performance on Roofs Exposed to Dry Contaminant

SURFACE and PROCEDURE	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effectiveness[b]	Planning Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effectiveness[b]	Planning Rate	No. of Men	Effort[c]
	r/hr	Residual Number	1000 ft2/hr		Man hrs/1000 ft2	r/hr	Residual Number	1000 ft2/hr		Man hrs/1000 ft2
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	29	.03	3.9	2	0.5	30	.01	3.9	2	0.5
FH-HSD-FH[a]	5	.005	4.8	5	1.0	12	.004	3.9	5	1.3
Tar and Gravel										
Firehosing	38	.04	1.5	4	2.7	38	.015	1.5	4	2.7
FH-HSD-FH[a]	10	.01	1.8	7	3.9	31	.01	1.8	7	3.9
Roll Roofing										
Firehosing	54	.05	3.0	2	0.7	54	.02	3.0	2	0.7
FH-HS-FH	15	.015	3.9	5	1.3	30	.01	3.3	5	1.5
Composition Shingle										
Firehosing	60	.06	3.0	2	0.7	70	.02	3.0	2	0.7
FH-HS-FH	31	.03	3.0	5	1.7	46	.015	2.7	5	1.8
Wood Shingle										
Firehosing	100	.10	2.1	2	1.0	200	.07	2.1	2	1.0
FH-HS-FH	50	.05	1.5	5	3.3	100	.03	1.5	5	3.3

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.
[b] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/intial standard dose rate:
[c] Effort, in man hrs/1000 ft^2, results from dividing the number of men involved by the planning rate: column 4/column 3.

Appendix B (iii)

Camp - Stoneman Trials

Table 5.6 Expected Recovery Performance on Roofs Exposed to Slurry Contaminant

	1000r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
Surface and Procedure	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ Hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	30	.030	2.7	2	0.7	38	.013	2.7	2	0.7
FH-HSD-FH[a]	7	.007	3.0	5	1.7	17	.006	2.7	5	1.8
Tar and Gravel										
Firehosing	55	.055	1.5	4	2.7	55	.018	1.5	4	2.7
FH-HSD-FH	45	.045	1.8	7	3.9	50	.017	1.8	7	3.9
Roll Roofing										
Firehosing	120	.12	1.8	2	1.1	120	.04	1.8	2	1.1
FH-HS-FH	55	.055	3.0	5	1.7	55	.018	2.7	5	1.8
Composition Shingle										
Firehosing	250	.25	1.8	2	1.1	250	.083	1.8	2	1.1
FH-HS-FH	170	.17	2.4	5	2.1	200	.067	2.4	5	2.1
Wood Shingle										
Firehosing	250	.25	1.5	2	1.3	250	.083	1.5	2	1.3
FH-HS-FH	170	.17	0.9	5	5.6	200	.067	0.9	5	5.6

[a]Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b]Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

[c]Effort, in man hrs/100 ft^2, results from dividing the number of men involved by the planning rate: column 4/column 3.

Appendix B(iii)

Miscellaneous Laboratory and Weapon Trials data on Offshore Waterburst fall-out (activity transferable)

Table 5.7 Expected Recovery Performance on Paved Areas and on Roofs Exposed to Wet (ionic) Contaminant

Surface	Procedure	Range of[b] Effectiveness (Residual Number)	Planning Rate (1000 ft^2 hr)	No. of Men	Range of Effort[c] (Man hrs/1000 ft^2)
Pavements	Motorized Flush'g	.50 - .75	27	2	.07
Concrete or	Firehosing	.55 - .85	9	6 - 8	0.7 - 0.9
Asphalt	FH-HSD-FH[a]	.35 - .55	9	11 - 13	1.2 - 1.4
	Heáter Planer[d]	.04 - .06	4 - 8	3 - 4	.4 - 1.0
Roofs					
Tar and Gravel	Firehosing	.20 - .30	1.5	4	2.7
	FH-HSD-FH[a]	.05 - .15	1.8	7	3.9
Roll Roofing	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.20 - .50	2.4	5	2.1
Comp. Shingles	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.25 - .55	2.4	5	2.1
Corrg. Metal	Firehosing	.60 - .90	2.4	2	0.8
	FH-HS-FH	.40 - .55	1.8	5	2.8
Wood Shingles	Firehosing	.75 - .85	2.4	2	0.8
	FH-HS-FH	.35 - .75	1.8	5	2.8

[a]Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b]Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

[c]Effort, in man hours/1000 ft^2, results from dividing the number of men involved by the planning rate.

[d]Restricted to surface removal of asphalt paving only. Greater rate based on use of skip loader for truck with debris. Lesser rate relies on 2 laborers to shovel debris into truck. The results of this destructive decontamination method shows that surface removal techniques are required to achieve low residual numbers.

Records.

CD/SA 96
Addendum

Home Office
Scientific Adviser's Branch

The Decontamination of Residential Areas

Application of U.S. performance data to a London District

J. McAulay

Introduction

1. American data on the decontamination of large areas are reviewed in Paper CD/SA 96. The object of the present supplement is twofold:

(i) To describe a method and chart for quick assessment of the equipment, manpower and time needed to decontaminate the pavements and streets in any built-up area under the wide range of conditions likely to be encountered in nuclear warfare and

(ii) To apply the chart and the U.S. experimental data to the decontamination of a typical heavily populated residential area about 7 miles south of the centre of London.

2. CD/SA 96 also mentioned British plans for public control in a contaminated area to avoid radiation sickness and possible death. These plans assume an initial period of up to 48 hours in a radiological refuge: for the following week or two, when possible, the daily periods of exposure out-of-doors to perform essential services or to get necessities for the family, should be limited to 2 hours in the more heavily contaminated and 4 hours in the less heavily contaminated zones. It is also shown that about two thirds of the total dose accumulated by people who will have to remain in the contaminated zones will be acquired during these short outdoor periods. The decontamination of access routes from houses to the local distribution centres in built-up areas therefore offers a possibility of reducing the subsequent dose to the population by a factor of two or more and of permitting an earlier resumption of normal community life and activities.

3. The effort required to decontaminate a built-up area will depend not only on the local intensity of radiation at the time but also on the water supplies and on the type and amount of equipment, particularly of mechanised equipment, available. In most European towns equipment will be the limiting factor which will determine when the work can be started, how long it will take and how many men will be needed within the restriction that none of them should get more than a limited and agreed dose of gamma radiation.

4. The inner commercial centres of towns, where the resident population is small, frequently have pavements wide enough to permit the passage of mechanised street cleaning equipment in spite of obstructions such as poles, lampposts, post boxes etc. near the pavement edge. In many residential districts the pavement width may be 7 ft. or less so that mechanised equipment might have to be confined to the street: in such cases a small contribution from the residents would be required to brush or wash contamination from the sidewalks and the pavement in front of each house into the street gutter.

5. Major limiting factors are the starting time t, and the working shift length i.e. the number of hours $\triangle T = t_1 - t_2$ that men can work in a contaminated area before they get the allowed dose of radiation D_a. It is assumed that the gamma dose-rate will decay as a function of $t^{-1.2}$ during the first few weeks after the nuclear detonation. If R_1 is the one hour reference dose-rate and if f the factor of protection afforded by any vehicle used for decontamination, then the dose D_a which may be incurred from t_1 to t_2 hours is

$$D_a = \frac{5 R_1}{f} \left\{ t_1^{-0.2} - t_2^{-0.2} \right\}$$

In the more heavily contaminated areas D_a may be accumulated in a single short work shift but in less heavily contaminated areas it will be possible for individuals to do repeated shifts separated by 8 or 12 hour rest periods: the work will take longer but will require less equipment and fewer men.

The allowed dose D_a

6. In the U.K. a Wartime Emergency Dose (WED) limit of 75r (100r under exceptional circumstances) has been accepted for Civil Defence life-saving operations. A limit has not yet been officially specified for decontamination operations and in this paper the 75r limit has been assumed to be applicable to the decontamination of access routes to permit the restoration of the essential activities of the community. Clearly, therefore, if the maximum use is to be made of specially trained men, the decontamination personnel must be given the best possible radiological protection during the early period of high dose-rate and rapid decay.

Transit dose

7. Decontamination crews will presumably operate from radiological shelters within the same district and they will not have to travel more than a few miles in an automobile at a speed of at least 30 m.p.h. Transit doses will therefore be negligible compared with the allowed dose D_a except in very heavily contaminated areas or where distances are more than 2-3 miles when the transit dose D_{trans} will have to be deducted from D_a. It may be calculated with sufficient accuracy for decontamination operations from the estimated transit time multiplied by the mean dose-rate over the distance to be travelled.

Starting time t, and duration of working shift (t_1-t_2)

8. Assuming a mean protective factor "f" over the transit and working time

$$\left(D_a - D_{trans}\right) f = 5R_1 \left\{ t_1^{-0.2} - t_2^{-0.2} \right\}$$

All variables other than time t can be grouped into one parameter

$$K = \left(\frac{D_a - D_{trans}) f}{5R_1}\right) = \left(t_1^{-0.2} - t_2^{-0.2} \right)$$

In Fig. 1 the shift duration $\Delta T = t_1 - t_2$ has been plotted against the starting time t_1 for a family of curves covering a range of likely or useful values of K. Fig. 1 can be used to determine any one of the variables ΔT, t_1 and K (and hence also of D_a) given the other two.

Heavily populated residential area in London

9. Details of a residential area to the north of Croydon and 7 miles south of the centre of London are given in Table 1. It consists mainly of rows of two or three storey terraced houses in streets at right angles to a main shopping and business thoroughfare: the latter consists of three storey terraced buildings with residences frequent in the upper floors.

Table I

Normal population	about 16,000
Total area (about 160 hectares)	399 acres
Streets length	73,000 ft.
Pavement widths	7 ft.
Area streets and pavements (67 acres)	2.92×10^6 sq. ft.

Other details

Open spaces other than house gardens			20.0 acres
Church buildings	(5)	plan area	0.67 "
School buildings	(3)	" "	0.58 "
Halls	(4)	" "	0.47 "
Public Library	(1)	" "	0.09 "
Pavilions and Club Houses	(4)	" "	0.24 "
Houses and shops	(4,453)	" "	63.70 "
Balance: back and front gardens of houses and courts of larger buildings			about 246 acres.

Decontamination techniques and types of equipment

10. The U.S. data related to the decontamination of a large paved area (airfield) from which the fall-out was pushed by mechanised road sweepers into windrows and carted away to a prepared dump or it was washed into drainage channels, round the periphery of the area by motorised flushing machines or hand operated fire hoses.

11. There is little reliable information on the likely density of fall-out deposits in relation to intensity of radiation. In this paper a range of 20 to 0.05 gms per sq. ft. is assumed (20 to 0.05 mg/cm^2). Thus over the pavements and streets of the London district under consideration, the amount of fall-out to be removed could range from 60 metric tons to a fraction of one ton.

12. British towns have a street drainage system which would greatly facilitate the disposal of all but the heaviest fall-out in sweeping it into the street gutters and then flushing or hosing it down into the drains. The U.S. rates of operation would be applicable to mechanised road sweepers with collector boxes and to motorised flushers, because of the time needed to empty the boxes or to fill the large water tanks. It is considered however that the U.S. rates for fire-hosing from a hydrant or pump and emergency reservoir would be too slow for British streets in which a road sweeper pushes the fall-out into the gutters and it is then hosed into the drains using the trailer pumps of the auxiliary fire service. (For very heavy fall-out the use of road sweepers with collector boxes would be preferable).

13. The performance data assumed in this paper for decontamination assessment are shown in Table 2.

Table 2

Equipment	Effectiveness % contamination removed	Number of crew per Unit	Rate of Operation sq. ft. per hour/unit	Assumed Protective Factor
A. Mechanised road sweeper U.S.	90	1	25,000	3
B. Motorised flusher (U.S.) 800 U.S. g.p.m. at 90 p.s.i.g.	98	2	30,000	2
C. Firehosing (U.S.) 100 g.p.m. at 80 p.s.i.g.	96	4 per nozzle	7,500	1.25 (see para 23)
D. U.K. Combined road sweeper and firehosing	96?	1 4 per nozzle	80,000 20,000	3 1.25

Application to a London District (Table 1)

(Area of streets and pavements 2.92×10^6 sq. ft)
Normal population 16,000

A. Mechanised road sweeper (U.S.) Crew 1. Da = 75r f = 3

14. If the job had to be completed in a single shift of 8 hours, fifteen machines and fifteen operators would be needed. If it could wait until decay permitted each man to do a repeat 8 hour shift after 12 hours rest then eight machines and eight men would be needed.

15. Estimated from the chart Fig. 1, the earliest starting times and the shift times for different one hour reference dose-rates are shown in Table 3.

Table 3

Mechanised road sweepers $f = 3$

Single 8 hour shift, 15 sweepers, 15 men			
R r.p.h.	K	Earliest shift hours	D_a r per man
10,000	.0045	H + 125 to H + 133	75
3,000	.015	H + 46 to H + 54	75
1,000	.045	H + 16 to H + 24	75
Two 8 hour shifts each for 8 men, 8 sweepers			
1,000	.030	H + 24 to H + 32	50)) 76
	.0157 (from Fig.1)	H + 44 to H + 52	26)
	.060	H + 12 to H + 20	50)) 69
500	.022 (from Fig.1)	H + 32 to H + 40	19)

16. If only a single machine were available and it was used continuously, the decontamination would take 117 hours. In an area of $R_1 = 1000$ r.p.h. and for $D_a = 75$ and $f = 3$, $K = 0.045$, it can be seen from Fig. 1 that if necessary a first 4 hour shift could start at H + 10 hours and decontamination could be completed by D + $5\frac{1}{4}$ days. A total of eight to nine men would be needed, working in 4 hour shifts with 12 hour rest periods between, each being replaced by another as he reached his limit of 75r. Even so, at least three of the nine men would get less than half the allowed dose with a balance of $1\frac{1}{2}$ "radiological lives" for other work.

17. It is clearly an advantage to use at least two mechanised sweepers and more where $R_1 \gg 1000$ r.p.h. since there is little difference between manpower needed to complete the work with eight machines during the third day and with one machine during the sixth day.

B. Motorised flusher (U.S.) Crew 2. $D_a = 75$r. $f = 2$

18. This technique is dependent on an ample supply of water. The water requirement is quoted as 500 U.S. gal. per 1000 sq. ft. so that for the total area of 2.92×10^6 sq. ft. of streets and pavements, 1.5×10^6 U.S. gal or 5700 m^3 of water would be needed (1 U.S. gal = 3.78 litres).

19. If the job had to be completed in a single working shift of 8 hours, 12 machines (24 men) would be needed. If it could wait until decay permitted each crew to work an additional shift (preferably in daylight) with a 12 hour rest period between, then the work could be done with 6 machines (24 men). The earliest starting times for different one hour reference dose rates have been estimated from Fig. 1 and are shown in Table 4.

Table 4

Motorised flusher f = 2

Single 4 or 8 hour shift for 24 men in 12 machines			
R_1 r.p.h.	K	Earliest shift hours	Da r/man
10,000	.0030	H + 185 to H + 189	75
3,000	.010	H + 65 to H + 73	75
1,000	.030	H + 24 to H + 32	75
Two 7 or 8 hour shifts each for 24 men in 6 machines			
1,000	.020 .012 (from Fig.1)	H + 35 to H + 43 H + 55 to H + 63	50) 80 30)
500	.040 .0184	H + 18 to H + 26 H + 38 to H + 46	50) 73 23)

20. If only one motorised flusher were available and it was used continuously, decontamination of the 2.92×10^6 sq. ft. of streets and pavement would take about 98 hours. In an area where R_1 = 1000 r.p.h. and for Da = 75 and f = 2, K = 0.030 it can be seen from Fig. 1 that a first 4 hour shift could start at H + 13 hours. A rough estimate can be made from Fig. 1 that not more than 20 men would be needed to decontaminate the whole area by about D + $4\frac{3}{4}$ days.

C. Firehosing by hand (U.S.)

21. This technique of decontamination would have to be used where no equipment other than that of the fire service was available. The U.S. data are based on the use of $1\frac{1}{2}$ inch hoses fitted with $\frac{5}{8}$ inch nozzles, delivering 100 U.S. gals. per minute at 80 p.s.i.g, with an overall manpower requirement of 4 men per nozzle and a cleaning rate of 7,500 sq. ft. per nozzle per hour.

22. The total water requirement would be about 2.4×10^6 U.S. gals. (9100 m^3) which is about 60% greater than that needed for motorised flushing. Lack of water would thus be a major limitation on the speed of decontamination in districts with only firehosing equipment.

23. In a heavily populated district where buildings are often continuous on both sides of the street, there will be a significant reduction in the average dose-rate because of the areas already cleaned. The fractional reduction will depend also upon the depth of front gardens and the roof areas in line of sight from operations in the roadway. In the selected London district (Table 1) front gardens were 5 ft. deep and in 2 storey houses the amount of visible roof was equivalent to the addition of 15 ft. to either side of the road i.e. a centre strip of 40 ft. in a total equivalent width of 80 ft. would be cleaned and this should reduce the dose-rate ultimately to considerably less than half its original value. Since two and probably three out of the crew of four men/nozzle will be working most of the time manning the pump and hauling the hose in a

cleaned part of the road, an average protective factor of 1.25 has been assumed for men engaged in firehosing streets and pavements in a built-up area.

24. If the job had to be completed in a single shift of 8 hours, 50 nozzles, 200 men and a total rate of water consumption of 0.3 million U.S. gals/hour (1130 m^3/hour).

Table 5

Firehosing single 8 hour shift f = 1.25
50 nozzles 200 men

R_1 r.p.h.	K	Shift hours	Da r/man
3,000	.0063	H + 98 to H + 106	75
1,000	.0188	H + 37 to H + 54	75
500	.0375	H + 19 to H + 27	75

25. If 25 nozzles and hoses were available, the teams could work in two consecutive shifts for a dose of 150r, the length of each shift being arranged so that each gets a dose of 75r. Here $K_2 = \frac{150 \times 1.25}{5R_1}$ and $K_1 = \frac{75 \times 1.25}{5R_1}$.

The whole district could then be decontaminated in $\frac{2.92 \times 10^6}{25 \times 7.5 \times 10^3}$ or about $15\frac{1}{2}$ hours.

Table 6

Firehosing Consecutive Shifts f = 1.25
25 nozzles 2 x 100 men

R_1	K_2	Consecutive Shift hours	K_1	Individual Shift hours
3,000	.0125	H + 89 to H + 104 (15 hours)	.0063 .0063	ΔT_1 $7\frac{1}{4}$ ΔT_2 $7\frac{3}{4}$
1,000	.0375	H + 32 to H + 47 (15 hours)	.0188 .0188	ΔT_1 $6\frac{1}{2}$ ΔT_2 $8\frac{1}{2}$
500	.075	H + 16 to H + 31 (15 hours)	.0375 .0375	ΔT_1 $6\frac{1}{2}$ ΔT_2 $8\frac{1}{2}$

D. Proposed British combined technique

26. This would be applicable to all but the heaviest fall-out deposits (i.e. much above $R_1 = 1000$). The decontamination would be carried out using a standard type road sweeping machine (without a collector box), which would sweep the fall-out into the street gutters and it would then be swept with firehoses down into the street drains: four $1\frac{1}{2}$ inch firehoses (each with a $\frac{3}{8}$ inch nozzle) could be fed by one existing type trailer pump of the British auxiliary fire service.

27. The road sweeper is assumed to afford protection by a factor $f = 3$. The rate of forward travel is normally just over 3 m.p.h. and assuming six passes over 40 ft. width of street and pavement and allowing about 25% of the time for servicing, the overall cleaning rate will be 80,000 sq. ft. per hour. The time required to sweep the whole area will be thus $2.92 \times 10^6/8 \times 10^4 = 36\frac{1}{2}$ hours.

28. Since firehosing in the open will follow behind the road sweeper it will not be realistic to start* decontamination earlier than about H + 16. For a one hour reference dose-rate, $R_1 = 1000$ r.p.h., Da = 75 $f = 3$, it can be estimated from Fig. 1 that three men each doing two 6 hour shifts with 12 hour rest period between, could sweep the whole area in about 36 hours getting doses of about 50, 40 and 30r respectively.

29. Firehosing would be started about H + 17: an average protective factor $f = 1.25$ (see paragraph 23) is assumed for men engaged in firehosing. A forward speed of about 1000 ft./hour per nozzle for driving fall-out along the street gutter down into the drains is considered to be reasonable. With one nozzle to each gutter and a paved width of 40 ft. this is equivalent to a cleaning rate of 20,000 sq. ft. per hour per nozzle.

30. One fire service trailer pump feeding 4 hoses and nozzles could keep pace with the road sweeper and clean the district in about 36 hours. In general, shifts of about 4 hours duration with a 12 hour rest interval will be preferable for this heavy manual work and unless illumination can be provided at night it will be desirable to limit firehosing to the hours of daylight.

31. Water consumption by the combined road sweeper and fire hosing technique would be $100 \times 60 \times 36 \times 4 = 0.86 \times 10^6$ U.S. gals or 3250 m^3 which, as one would expect, is considerably less than the amount needed either for the motorised flusher or for the firehosing technique alone.

32. If firehosing were carried out continuously with 4 nozzles from H + 17 to H + 53 (i.e. one hour behind the road sweeper), 9~~6~~ crews each of 16 men (total 144 ~~96~~ men) working in 3 or 4 hour shifts with 12 hours off, would be needed and of these, three ~~one~~ crews of 16 men would receive only about one ~~third~~ half of the allowed dose.

33. If firehosing were suspended during the night 5 crews of 16 men (total 80 men) using 4 nozzles could probably complete the decontamination by D + $3\frac{1}{2}$ days - alternatively with two trailer pumps and 8 nozzles and 160 men, appropriate daylight shifts could be worked out from Fig. 1 to have the work completed by about D + $2\frac{1}{2}$ days.

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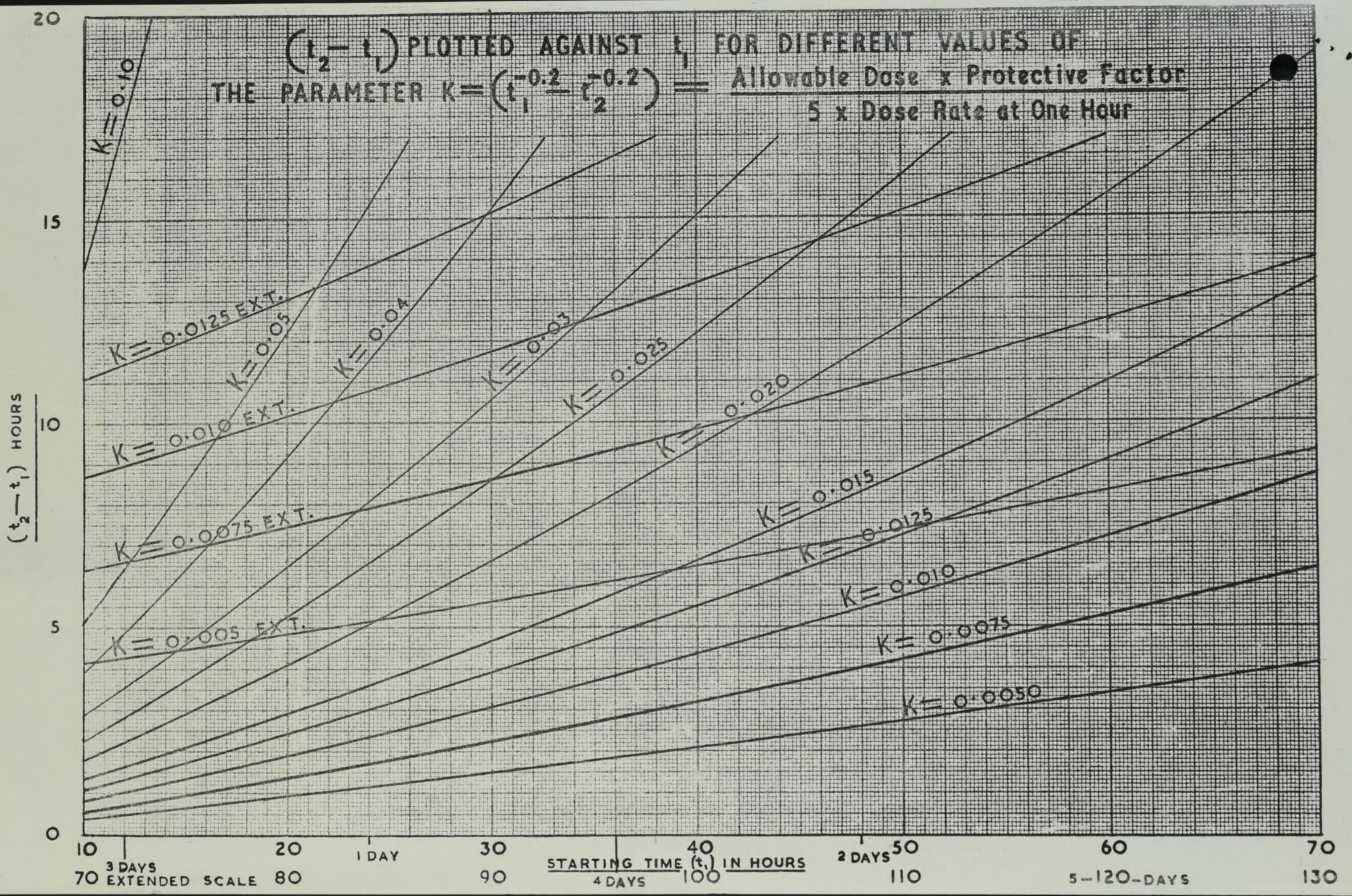
*In heavily contaminated areas the work should not start before 48 hours but shortage of equipment may make it desirable to start as soon as possible in some districts so that others will not have to remain contaminated for excessively long periods.

Table 7

Comparative Summary

Paved Area to be decontaminated
2.92×10^6 sq. ft. (= 27 hectares)
for R_1 = 1000 r.p.h. and Da = 75r

Technique	Equipment	Man hours	Time
A. Mechanised road sweeper (U.S.)	15 sweepers	15 x 8 = 120	H + 16 to 24
B. Motorised flusher (U.S.)	12 flushers	24 x 8 = 192	H + 24 to 32
C. Firehosing (U.S.)	50 Nozzles	200 x 8 = 1600	H + 37 to 45
D. Combined U.K. road sweeper, trailer pump and firehoses	1 sweeper 1 trailer pump 4 nozzles	3 x 12 = 36 9 x 16 x 4 = 596 total 612	H + 17 to 53



$(t_2 - t_1)$ PLOTTED AGAINST t_1 FOR DIFFERENT VALUES OF
THE PARAMETER $K = (t_1^{-0.2} - t_2^{-0.2}) = \frac{\text{Allowable Dose x Protective Factor}}{\text{5 x Dose Rate at One Hour}}$
$(t_2 - t_1)$ HOURS
STARTING TIME (t_1) IN HOURS
70 EXTENDED SCALE
3 DAYS
1 DAY
2 DAYS
4 DAYS
5-120-DAYS
K = 0·10
K = 0·05
K = 0·04
K = 0·03
K = 0·025
K = 0·020
K = 0·015
K = 0·0125
K = 0·010
K = 0·0075
K = 0·0050
K = 0·0125 EXT.
K = 0·010 EXT.
K = 0·0075 EXT.
K = 0·005 EXT.
0
5
10
15
20
10
20
30
40
50
60
70
80
90
100
110
130

NOTE: these Confidential-classified reports by UK Home Office Scientific Adviser's Branch physicist George Reginald Stanbury, OBE (1903-73) refer to the 1957 edition of Glasstone's book Effects of Nuclear Weapons (based on nuclear test data for civil defence, not the false computer simulations later published).

Stanbury attended the 1952 Operation Hurricane UK nuclear test and analysed thermal and fallout data. This paper compares fallout areas in Glasstone and other sources like the Classified 1957 USA Capabilities of Atomic Weapons TM 23-200 and the 1959 UK Manual of C.D. v1 pamphlet 1, Nuclear Weapons booklet.

The latter shows that a 1 megaton fission surface burst gives 30 R/hr at 48 hours after burst over an area of ~50 square miles: this comes from Table 9.71 in Glasstone, 1957: the elliptical fallout belt for 15 mph wind is 22 miles long and 3.1 miles in maximum width, thus having an area of (Pi/4)(22)(3.1) = 52 square miles. For comparison, Fig. 4-14B in the Confidential American manual TM 23-200 Capabilities of Atomic Weapons, gives an area of just 28 square miles.

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Downwind fallout areas from ground-burst megaton explosions

1. **Information available in 1958**

At the time of writing the 1959 edition of the U.K. pamphlet "Nuclear Weapons", three basic sources of information on the extent of downwind fallout were available to Scientific Adviser's Branch.

(i) The U.S. publication "The Effects of Nuclear Weapons" paragraphs 9.71 to 9.73

(ii) The U.S. publication "Capabilities of Atomic Weapons" fig. 4 -4B, prepared by the Armed Forces Special Weapons Project; originally highly classified but now downgraded to "Confidential". This is at present under revision.

(iii) The report of the 1957 U.S. Congressional Hearings into "The nature of radioactive fallout and its effects on man".

No quantitative data is given in (iii) neither can any useful figures be deduced therefrom.

The fallout areas given in (i) are larger than those given in (ii) for the higher dose rate contours, but smaller for the low dose rate contours, especially for the larger weapons. However as (i) was the only widely available source at the time of going to press it was decided to use the data from (i) in preference to that from (ii). However, in Scientific Adviser's Branch the Capabilities (ii) data is considered to be the more reliable, chiefly because it is the data which is always used by the U.S. military.

A comparison of the various figures for a few dose rates is given in Table 1.

Table 1

Areas of downwind contamination (sq. miles)

Dose rate contour @ H + 1 r.p.h.	1 MT; 100% fission		10 MT; 100% fission	
	(i) E.N.W. & U.K. Nuclear Weapons	(iii) Capabilities	(i) E.N.W. & U.K. Nuclear Weapons	(iii) Capabilities
3000	54	27	540	650
1000	210	110	2100	1750
300	650	350	6500	5000
100	1500	1100	15000	18500
30	3300	3500	33500	43000

N.B. The Capabilities data is approximately summarised in the expression

$$AR = \frac{10^5}{p^{-1.2}}$$

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Where A = area in sq. miles

R = dose rate contour in r.p.h.

P = power of weapon in MT

($P^{-1.2}$ can always be obtained from a radiac calculator)

The trials on which this data are based were carried out in the Pacific where the problems of adequate instrumentation over vast areas of sea are almost insuperable; the accuracy of the data should not therefore be too highly rated.

It should also be noted that in this country the low dose rate contours are of comparative insignificance. H + 1 contours of 30 and 300 for example define the outer and inner limits of the X zone. If exposure is assumed to start at H + 1 this would correspond to cumulative doses in the open of 80r to 800r; at the end of the fallout plume where fallout did not arrive until say H + 5, these doses would be halved. Even with a protective factor as low as 20, the cumulative dose to H + 48 could not therefore exceed 40r in the X zone under the worst circumstances.

For most attack situations in this country the greater part of the downwind W and X zones would be in the North Sea.

For practical planning purposes therefore we are not very interested in the areas for contour values much lower than 100 r.p.h. @ H + 1 and discrepancies between different sets of data below this region are of academic interest only.

Information available since 1958

We now have further information available to us from the 1959 U.S. Congressional Hearings on "Biological and environmental effects of nuclear war". It must be stressed, however, that this is not new information since no further trials have been held in the meantime; it is based on fresh appraisals of old data and new methods of presenting it.

The information appears in three forms which will be examined later in greater detail

(a) In the early part of the 1959 Congressional Hearings, Shelton gives the basis of the assumptions used in the exercise to study the overall effect of an attack by 263 megaton weapons on 224 targets in the U.S.

(b) In a paper by Triffet of the U.S. Naval Radiological Defence Laboratory a number of typical fallout patterns are reproduced

(c) In a paper by Knapp - also of the U.S. N.R.D.L. - an account is given of theoretical work by Miller from which certain deductions can be made about the extent of downwind fallout.

(a) The basic U.S. exercise assumptions

page 15 "An accumulation of about 700 rem in 48 hours for an unshielded person can be expected to occur over about 1500 sq. miles from a 10 megaton surface burst (50% fission).

page 41 Table 1 (also for 50% fission).

450 rem in 48 hours (no shielding) (1MT - 200 sq. miles
(10MT - 2,500 sq. miles

Page 32 "A 600 r per hour dose rate contour for a 1MT surface burst, with our assumed 50% fission, would enclose an area of about 80 sq. miles; for a 10MT weapon with a 50% yield due to fission, the 600r per hour contour would enclose about 1,300 sq. miles.

It is not clear from the test when people were considered to have been first exposed. It cannot have been sooner than H + ½ otherwise the fallout would not have been down; it cannot have been much later than H + 2 because by that time with the very high winds assumed, the fallout would have been almost out of the territory. On these two extreme assumptions therefore, the total dose figures given in pages 15 and 41 have been transformed into a range of possible H + 1 contours for direct comparison with the data on page 32 and that from Capabilities.

In order to make this comparison possible, sealing laws must be assumed for the power of the bomb and the fission yield. In Capabilities, bomb power sealing is accounted for because the relation between total yield = fission yield and areas is given graphically for a range of H + 1 contours from 3000 down to 10 r.p.h. Where only X% of the total yield is due to fission, the dose rate contour for a given area must be multiplied by $\frac{X}{100}$.
Similarly to obtain the area for a particular dose rate contour, the value of the dose rate must be divided by $\frac{X}{100}$ and the area of the resultant dose rate read from the figures opposite the total yield.

The result of the comparison on the above basis is shown in Table 2.

Table 2

Areas of downwind contamination (sq. miles)
(Comparison of U.S. Basic exercise data with Capabilities)

Dose rate contour @ H + 1 rph	1 MT; 50% fission		10 MT; 50% fission	
	U.S. Exercise data	Capabilities	U.S. Exercise data	Capabilities
p15 (FOA @ H+½ 200	-	-	1500	3800
p15 (FOA @ H+2 340	-	-		2400
p41 (FOA @ H+½ 130	200	470	2500	5700
p41 (FOA @ H+2 215		230		3500
p32 600	80	70	1300	1200

For the p15 and p41 values, it is the lower estimate of dose rate contour @ H + 1 (corresponding to F.O.A. @ H + 2) which gives the better agreement. Even so the values used in the U.S. exercise seem to be lower than those given in Capabilities and lower again than those given in ENW and U.K. Nuclear Weapons. There is good agreement as on p32 where the dose rate contour is quoted directly, and the value has probably been quoted direct from Capabilities.

(b) The fallout pattern

This is Fig. 7 on page 80 of the 1959 Congressional Hearings and is stated to be for a 5 MT explosion. No fission yield is actually given although, as the whole of the article in which this pattern appears is concerned with a 50% fission yield weapon, it seems reasonable to assume that this pattern is also intended for a 50% fission yield.

The 25 r.p.h., 100 r.p.h. and 500 r.p.h. contours have been integrated and the areas compared with those from Capabilities in Table 3.

Table 3

Areas of downwind contamination (sq. miles)
Comparison of U.S. fallout pattern with Capabilities

Dose rate contour @ H + 1 r.p.h.	5 MT: 50% fission	
	Fig. 7. p.80 1959 Hearings	Capabilities
500	2,000	750
100	6,000	3,300
25	30,000	12,000

In this case the areas calculated from Fig. 7 are two or three times higher than the Capabilities figures.

However it is interesting to note that this same pattern of contamination was published on page 304 of the 1957 Congressional Hearings. Contour values were not quoted, but the shapes are identical and the corresponding contours can easily be identified. When this is done it is readily seen that the linear dimensions of the 1957 pattern are only half those of the 1959 pattern, so that the areas are smaller by a factor of four!

This discrepancy has never been publicly acknowledged, and there seems to be no sure way of finding out which is correct; the 1957 version looks much more reasonable.

It is of interest that this particular pattern was for an extremely low wind condition (3 or 4 m.p.h. mean vector wind) whereas the Capabilities figures are for a 15 m.p.h. mean vector wind. However, although this will affect the shape of the pattern, it does not (according to Capabilities) affect the total area under a given contour.

(c) Theoretical work at the U.S. N.R.D.L.

This work is summarised in a paper by Knapp, starting at page 113 of the 1959 Congressional Hearings. Miller has made a complete reappraisal of the fallout decay schemes based on all the latest data for the individual decay schemes of all the fission product nuclides and he concludes that the gamma radiation energy emission rate during the first day is about twice as high as was previously assumed and published in E.N.W. But these theoretical estimates of gamma energy output have never been used in the past to calculate the sizes of fallout areas which have always been based on measurements, however unreliable those measurements may have been.

Even so, it is interesting to do the sums.

The N.R.D.L. data (page 126) states that 1 KT of fission products will contaminate an infinite flat plane, 1 sq. mile in extent to a dose rate of 3,360 r.p.h. @ H + 1. Thus 1 MT (100% fission) produces 3.36×10^6 r.p.h. sq. miles.

For comparison with measured values this must be reduced because of two well known facts

(a) Less than 80% (and probably not more than 60%) of the fission products are deposited in the main fallout area; the remainder goes up into the stratosphere and is eventually deposited as world wide fallout.

and (b) The measured dose rate under practical conditions is only three quarters to one half of the calculated dose rate for an infinite flat plane.

Thus we can assume for a practical case that -

$$1 \text{ MT } (100\% \text{ fission}) \ngtr 3.36 \times 10^6 \times .8 \times .75$$

$$\ngtr 2 \times 10^6 \text{ r.p.h. sq. miles}$$

The best integration that can be made of the E.N.W. data gives a figure not much more than half this, so that on these grounds we might conclude that the figures published in U.K. Nuclear Weapons (which are the same as E.N.W.) are too low by a factor of nearly 2.

In pages 189 to 229 of the 1959 Congressional Hearings, there is a record of a long "Round Table Panel Discussion on the Basic Properties and Effects of Radioactive Fallout" which is largely concerned with this factor of two. The discussion was inconclusive but the following quotation from page 193 is of interest.

"Dr. Machta. Since we in the Weather Bureau were primarily responsible for preparing the O.C.D.M. local fallout patterns, I would like to justify what we did. We did not use in any way the conversion in the Effects of Nuclear Weapons or the N.R.D.L. conversion, because it was unnecessary to do so.

In the Pacific we detonated a bomb of X megatons. We observed the distribution of fallout as dose rate readings. Then we scaled this pattern to other megaton yields. In doing this we did not have to employ the conversion in question at all. The fallout isolines are essentially correct."

This business of "fission product accountancy as it is often called, has always produced confusing and conflicting results. Of necessity no proper account can be taken of induced activities, the loss of volatile fission products and fission products with volatile precursors and so on, and the line taken by Dr. Machta seems to be more reasonable, although it is still then necessary to depend on basic measurements which are none too reliable.

Conclusions

Having examined all the evidence, we are not convinced that there is any justification for multiplying the U.K. Nuclear Weapons areas by two. These figures are mostly higher than those given in Capabilities which are again higher than those by the U.S. in their 1959 exercise. If the latter figures had in fact been multiplied by two as was suggested by the Chairman at the Round Table Discussion, they would have agreed fairly well with the figures published in the U.K. Nuclear Weapons pamphlet.

G. R. STANBURY

November 1960.

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THE IMPLICATION OF "CLEAN" BOMBS FOR CIVIL DEFENCE

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MARCH, 1964

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SCIENTIFIC ADVISER'S BRANCH

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The implication of "clean" bombs for civil defence

G. R. Stanbury

Summary

The nature of the fallout from a ground burst, 10% fission yield bomb is examined.

Because of the large neutron release from such a weapon, the total radioactivity - consisting chiefly of sodium 24 induced in the constituents of the soil - is shown to be of the same order as from a 50% fission weapon as currently estimated.

In the first week, two-thirds of the total dose from such an explosion is contributed by the induced sodium 24. After the first week this activity disappears and the residual hazard from the fission products is down by a factor of 5.

This would make possible a substantial easing of the public control procedure after the first week and would result in a 5-fold reduction in the hazard from contaminated food and water.

Because of the effect of sodium 24 on the overall decay rate, predictions of future dose rates made at early times can be out by a factor of 2 or 3 times if based on the $t^{-1.2}$ decay law for mixed fission products.

For all these reasons it is essential to have a system of fallout collection and analysis which enables the nature of fallout to be established as soon as possible. Such a system is being developed for use in the U.K. Warning and Monitoring Organisation.

Introduction

Published data on fallout from nuclear explosions is based largely on the assumption of a 100% fission yield. While this may be sufficiently valid for a kiloton explosion it is certainly not valid for a thermonuclear explosion in the megaton range, and even at the 1959 U.S. Civil Defence Congressional Hearings it was stated that the average fission yield for all nuclear explosions up to that date had been only 50%! In the 1962 edition of the U.S. "Effects of Nuclear Weapons", scaling laws are given for modifying the idealised fallout patterns for a range of fission yields.

More recently both Russia and the U.S. have announced their ability to produce "clean" bombs, and a figure of as low as 7% fission yield has been quoted. There is a discussion of the general radiological effects of low fission yield explosions in the early part of Chapter IX of E.N.W.(1962).

In this paper an attempt is made to assess the implications of the fallout from such a weapon in comparison with the more usual 50% fission yield. The particular aspects covered are:-

(1) The total amount of radioactivity produced and its variation with time.

(2) The variation of the accumulated dose with time.

(3) The extent of fallout contamination.

(4) The effect of the energy of the radiation on the estimation of the protective factors of buildings.

(5) The effect of the overall decay rate at early times on the prediction of future dose rates.

(6) The effects of 1 to 5 on

(a) the Provisional Scheme of Public Control in Fallout Areas

and (b) internal radiological hazards.

The comparison with a "50% fission yield" is somewhat complicated by the fact that in civil defence, the radioactivity from a ground burst 50% fission yield bomb has always been assumed to consist solely of mixed fission products and the presence of any neutron-activated components has been neglected. For the extent of contamination the usual practice has been to accept the published US dimensions for the idealised fallout patterns and then apply the recommended scaling procedure to find the appropriate dimensions for a 50% fission yield.

1. The radioactivity produced and its variation with time

Consider a 1 megaton ground burst nuclear explosion with a 10% fission yield.

Using the generally accepted value of 1.45×10^{23} fissions per KT, the number of fissions to produce 100 KT is 1.45×10^{25}. If each fission produces between 1 and 1.5 spare neutrons the total number produced is about 2×10^{25}.

For the fusion part of the reaction, one neutron is produced for about 12 MeV of energy.

$$900 \text{ KT} = 900 \times 2.63 \times 10^{25} \text{ MeV}$$

so that the number of neutrons produced from fusion is

$$\frac{900 \times 2.63 \times 10^{25}}{12} = 2 \times 10^{27}$$

This is 100 times greater than the number produced in the fission part of the reaction and can, in effect, be regarded as the main source of available neutrons.

The proportion that escape the confines of the weapon must be critically dependent on weapon design, but published tables of neutron doses at different distances from the point of detonation suggest that the figure may not be much in excess of 20% of which half escape upwards, and half (about 2×10^{26}) go downwards to be absorbed into the materials of the ground.

Using a typical soil analysis table and multiplying the proportion of each element according to the number of atoms present by the appropriate neutron cross-section, the proportions in which induced activities are produced in the constituents of the soil can be calculated. For Nevada soil for which a complete soil analysis table is conveniently available, nearly 40% of all neutrons are absorbed by hydrogen atoms to produce non-radioactive deuterium; about 4% produce sodium 24 and 1% produce manganese 56. For a variety of reasons, the remaining constituents of the soil produce very little induced activity.

The proportions by weight of sodium (1.6%) and manganese (.04%) in Nevada soil are less by half than that of the world average for the earth's crust, but are higher than those for clay which is common in the U.K. For building materials as a whole - according to information supplied by the Building Research Station - the proportion of manganese is about the same as that for Nevada soil but the proportion of sodium is only one tenth; but even in the most heavily built-up areas, buildings do not cover more than 25% of the land area. Standard 1 : 2 : 4 concrete contains 1.2% sodium largely owing to the high sodium content of the gravel ballast.

In general it seems fair to assume that the figure of .04% for manganese is typical of conditions in the U.K. but that the figure of 1.6% for sodium is probably on the high side. For subsequent calculations we shall however use the Nevada soil figures and assume that 4% of all the available neutrons produce sodium 24 and 1% produce manganese 56.

It is important to realise that there are considerable variations in soil constitution from one part of the country to another and these will produce corresponding variations in induced activity; the following calculations are therefore only an example of what is possible.

The choice of values for the gamma ray energy per fission for mixed fission products at different times is very large. It is proposed to adopt the 1 day value of 2×10^{-6} MeV per sec per fission given in N.R.D.L. Report TR 187 and use the $t^{-1.2}$ law to calculate other values. This is not strictly justifiable at early times but has been found to be sufficiently accurate for actual fallout material, the constitution of which is modified by fractionation effects and by the presence of neptunium 239.

For a comparison of activities at different times the following times are of special interest

(i) t = H + 1 hours, the usually accepted standard time

(ii) t = H + 1½ hours, the time usually assumed in civil defence exercises and studies as an average for the first arrival of fallout

(iii) t = a time at which the ratio of the gamma energy release rate of the nuclide to that of the fission products is a maximum. This always occurs when t = 1.73 x half life of nuclide in which case

$$e^{-\lambda t} = 0.3$$

For sodium 24 this is 26 hours and for manganese 56, 4.5 hours.

(iv) t = 48 hours, the time used for the delineation of the WXYZ zones as defined in the Provisional Scheme of Public Control (Manual of Civil Defence, Pamphlet No. 2).

The following table gives the various basic and comparative figures for a 1 MT nuclear detonation with a 20% neutron escape based on the foregoing assumptions:

Table 1

Basic nuclear data for 1 megaton and 20% neutron escape

	50% fission yield with no additional induced activity	10% fission yield		
	F.P.	Na 24	Mn 56	F.P.
Number of fissions	7.25×10^{25}			1.45×10^{25}
Proportion of neutrons absorbed		4%	1%	
Number of activated atoms at t = 0		8×10^{24}	2×10^{24}	
Half life in hours		15	2.6	
Decay constant λ (sec^{-1})		1.28×10^{-5}	7.4×10^{-5}	
Disintegrations per sec at t = 0		10.24×10^{19}	14.8×10^{19}	
Gamma energy per disintegration; MeV		4.2	1.8	
Gamma energy release rate in 10^{20} MeV/sec				
at t = 0		4.30	2.66	
t = 1	66.5	4.11	2.04	13.3
t = 1½	40.8	4.02	1.79	8.16
t = 4.5 (Max. proportion time for Mn 56)	10.9	3.49	.80	2.18
t = 26 (Max. proportion time for Na 24)	1.32	1.29	.003	.264
t = 48	.64	.465	.000	.128

With 10% fission, the maximum share of the dose rate contributed by manganese 56 at H + 4.5 hours is 12½%. After H + 10 hrs. its contribution is less than 5% and drops rapidly thereafter.

The contribution from sodium 24 is equal to that from fission products at H + 3 hours when it constitutes more than 40% of the total. The share increases to a maximum value of 83% at H + 26 hours, drops to 78% at H + 48 hours, is about 50% again at H + 90 hours and drops to 5% at H + 1 week. After this the contribution rapidly becomes negligible; at H + 10 days it is only 0.3%.

The dose rate/time relationship for the 10% fission yield case is shown graphically in Fig. 1. The plot is a log-linear one such as is used at Sector Operations Centres in the UK Warning and Monitoring Organisation, which has the advantage that the shape of the decay curve is independent of the starting level and time of burst, and one template only can be used for curve fitting.

2. The variation of the accumulated dose with time

It will be seen from Fig. 1 that if exposure to fallout from a 10% fission yield bomb starts at any time from about H + 2 or 3 hours onwards, the major part of the dose accumulated in the first day or so is from sodium 24. However, it has been the custom in the Home Office to use H + 1½ hours as the average arrival time for fallout and the following table of accumulated doses (Table 2) has been calculated on this basis.

There are a number of ways in which dose comparisons can be made depending on the particular time at which the dose rates are assumed to be standardised. As already noted, the present Provisional Scheme of Public Control in Fallout is based on the delineation of various zones of activity in which the boundaries are defined in terms of the dose rate at H + 48 hrs [for all practical purposes this is 1% of the dose rate at H + 1 hour for an all-fission yield]. The YZ zone boundary in particular is defined as 10 r.p.h. at H + 48 hours, and it is proposed therefore to make the comparison of doses on the assumption that a dose rate of 10 r.p.h. is reached - by whatever path - at H + 48 hours. Accumulated doses for other dose rate levels at this time will be in proportion. The results of the calculations are as follows:-

Table 2

Accumulated doses in the open (in roentgens) for 10 roentgens per hour at H + 48 hours from a 10% fission yield (assuming 20% neutron escape) and from mixed fission products only

	Mixed fission products obeying $t^{-1.2}$	10% fission yield			
		Na 24	Mn 56	F.P.	Total
Dose rate (r.p.h.)					
at H + 48	$\boxed{10.0}$	7.84	-	2.16	$\boxed{10.0}$
H + 0	-	72.3	44.7	-	-
H + 1	1050	69.0	34.3	225	328
H + 1½	650	67.4	29.4	140	237
Dose (r) from					
H + 1½ to H + 8	1390	379	93	293	765
H + 16	1850	710	110	393	1213
H + 24	2050	940	112	435	1487
(2 days) H + 48	2420	1286	113	513	1912
(1 week) H + 168	2940	1450	113	627	2190
(1 month) H + 720	3430	1450	113	728	2291

The dose/time relationship for 10% fission yield is shown graphically in Fig. 2.

As already noted, there is no further appreciable dose increase from manganese 56 after H + 10 hours, and from sodium 24 after a week.

During the first week, the overall dose from a 10% fission bomb (2190r) is less than from all fission fallout (2940r) by 25%.

After the first week, any additional dose is derived solely from the fission products so that at the end of the first month for example the dose from a 10% fission yield bomb (2291r) is 33% less than from all-fission fallout (3430r).

During the first week, sodium 24 contributes 64% of the total dose from a 10% fission bomb.

3. The extent of fallout contamination

The most useful areas for comparison are those of the Public Control Zones, the boundaries of which are 10 rph, 3 rph and 0.3 rph at H + 48 hours.

For all the civil defence exercises and studies to date, these areas have been deduced from the data published in TM23-200 for a 100% fission yield bomb, with a 15 knot wind, scaled by the recommended methods to 50% fission yield and a 30 knot wind.

For the 10% fission yield case the only practicable method seems to be to take the total activity at H + 48 hours as given in Table 1, namely $.593 \times 10^{20}$ MeV/sec and compare it with the figure for a 100% fission yield of $2 \times 0.64 = 1.28 \times 10^{20}$ MeV/sec giving an "apparent" fission yield of 46.5%. This is so close to the value of 50% assumed in the usual method that it cannot possibly make any difference to the size of the Public Control Zones.

4. The effect on the estimation of the protective factors of buildings

As we have seen, for a ground burst 10% fission yield bomb with a 20% neutron escape, almost 2/3rds of the dose in the first week is contributed by sodium 24 (the contribution from manganese 56 can be neglected for this purpose).

The 4.2 MeV of gamma ray energy per disintegration of sodium 24 is contributed by two photons with energies of 1.4 and 2.8 MeV respectively; the first contributes one third of the sodium 24 dose, and the second the remaining two thirds.

The standard Home Office method of estimating the protective factors of buildings is based on a less penetrating 1.0 MeV gamma radiation which is assumed to be typical of fission product radiation at early times. The following figures for attenuation by concrete are interpolated from "An anthology of health physics data" by Dunster - UKAEA 1957.

Table 3

	1 MeV	1.4 MeV	2.8 MeV
Attenuation through 15" concrete	30	20	8
Average factor for radiation from 10% fission bomb during first week	←	18	→
Attenuation through 20" concrete	110	70	20
Average factor for radiation from 10% fission bomb during first week	←	61	→

Thus in calculating the penetration of radiation from 10% fission yield fallout through the walls and roof of a building, the amount should be increased by about 50 to 100% depending on the thickness of the walls and the weight of the overhead cover. Protective factors as estimated by the present points scheme would be between 30% and 50% too high.

5. The effect of the overall decay rate on the prediction of future dose rates

It is the present practice in the UK Warning and Monitoring Organisation to calculate DR7's (i.e. dose rates at H + 7 hours) for a given Royal Observer Corps post as soon as it is established that fallout maximum has been reached at that post. Later this is adjusted when it is known that fallout is complete. In calculating the DR7, the $t^{-1.2}$ decay law is normally used.

These DR7's are then plotted on a map of the area and contours for specific dose rates drawn in. From these contours the zone boundaries can readily be estimated.

The presence of a substantial amount of sodium 24 affects the overall decay rate substantially. Initially, for a 10% fission bomb, the activity of the fission products decays much faster than that of sodium 24. At about H + 9 hours the slopes are equal, but from H + 24 hours onwards the sodium 24 activity decays about five times more quickly than does the fission product activity until after about a week when it's contribution is negligible.

The expression for the total dose rate at any time from a 10% fission bomb which produces 10 r.p.h. at H + 48 can be derived from the figures in Table 2, namely

$$\underset{\text{(r.p.h.)}}{\text{Dose rate}} \text{ at } \underset{\text{(hrs.)}}{\text{time } t} = \underset{\text{(f.p.)}}{225\, t^{-1.2}} + \underset{\text{(sodium 24)}}{72.3\, e^{-.0463t}} + \underset{\text{(manganese 56)}}{44.7\, e^{-.266t}}$$

If the dose rate is measured at any time between the completion of fallout and H + 48 hours and the DR 48 for example estimated by applying the $t^{-1.2}$ decay law, the results are as shown in Table 4.

Table 4

Comparison of DR48's predicted at early times, with actual values. (10% fission)

Time of prediction of DR48	DR48 (r.p.h.)	
t (hours after burst)	Estimated at time t	Actual
2	4.2	10
4	6.0	10
8	8.7	10
12	10.5	10
16	11.7	10
20	12.3	10
24	12.7	10
36	12.1	10
48	10.0	10

Thus the predicted DR 48 could be in error by a factor of more than 2 if the prediction is made at very early times. From about H + 8 hours onwards on the first day the error in the estimated DR 48 is hardly worth worrying about. Even this error can be allowed for if the actual decay rate is known from measurements on deposited fallout at early times such as is now being planned for at R.O.C. Posts. Errors are likely to be more serious for predictions of dose rates for times during the operational life-saving and fire fighting period, especially if these are made too early on. It would be doubly important for operational groups to keep a close watch on their instruments.

6(a) The effect of "clean bombs" on the Provisional Scheme of Public Control in Fallout areas

The effects of "clean bombs" can so far be summarised as follows:-

For a 20% neutron escape, the induced sodium 24 contributes three quarters of the dose rate at the end of the first day but only 5% at the end of the first week, after which its contribution is negligible. It contributes two-thirds of the total dose in the open in the first week.

This total dose in the first week is about 25% less than would have been accumulated if all the fallout had been fission products.

Because of the higher energy of the sodium 24 radiation, our present estimates of the protective factors of buildings are probably too high by 30-50% if the results are applied to bombs of 10% fission yield.

Predictions of DR 48's made in the first six hours may be too low by a factor of two. Predictions made at later times are not likely to be far out.

The Provisional Scheme of Public Control provides basically for

(i) evacuation of people from zones where the DR 48's are greater than 10 r.p.h. at some time subsequent to H + 48 hours

(ii) the establishment of regimes of living in the less heavily contaminated zones which, by reducing the proportion of the time spent in the open, keep radiation doses below a dangerous level.

We have seen that for a given DR 48 doses in the open from a 10% fission yield bomb are likely to be about 25% lower than from a 50% fission yield bomb as currently estimated (i.e. assuming all the fallout is mixed fission products), but this is largely offset by the correspondingly greater penetration of the sodium 24 radiation into buildings. Thus any action based on a consideration of the doses already accumulated by people in buildings would not have to be changed.

However the question of evacuation of the Z zone is mainly determined by the difficulty of maintaining some kind of normal life in the zone after the first week. This would obviously be easier in the case of a 10% fission bomb because the residual dose rates after a week would be lower by a factor of about 5; this would be to the advantage of the occupants in relation to their subsequent living regime and to people sent in from outside and it would almost certainly be possible to carry on without evacuation. The sooner this possibility is established and made known to Controllers the better.

Similarly in the Y zone no change in the first week would be justified, but it is clear that the regime of living could be substantially relaxed thereafter.

In general the delineation of zone boundaries should not be carried out before about H + 6 hours and, in fact, need not be carried out before this. Even in the absence of any direct data from fallout deposition measurements, predictions of DR 48's made subsequently to H + 6 hours are likely to be accurate enough for most purposes, and by this time the nature of the fallout should have been roughly established.

6(b) Internal radiological hazards

Because of the rapid decay of the sodium 24 radiation after the first week, the hazard from contaminated food and water is likely to be much reduced since most of the sodium 24 activity is gone before it gets through the normal food and water chains, and the residual fission product activity is down by a factor of 5 for a 10% fission yield bomb.

March 1964.

SAN/59 6/15/2

Fig. 1. Relation between gamma ray energy release rate and time after burst for a 1 megaton ground burst with a 10% fission yield and a 20% neutron escape.

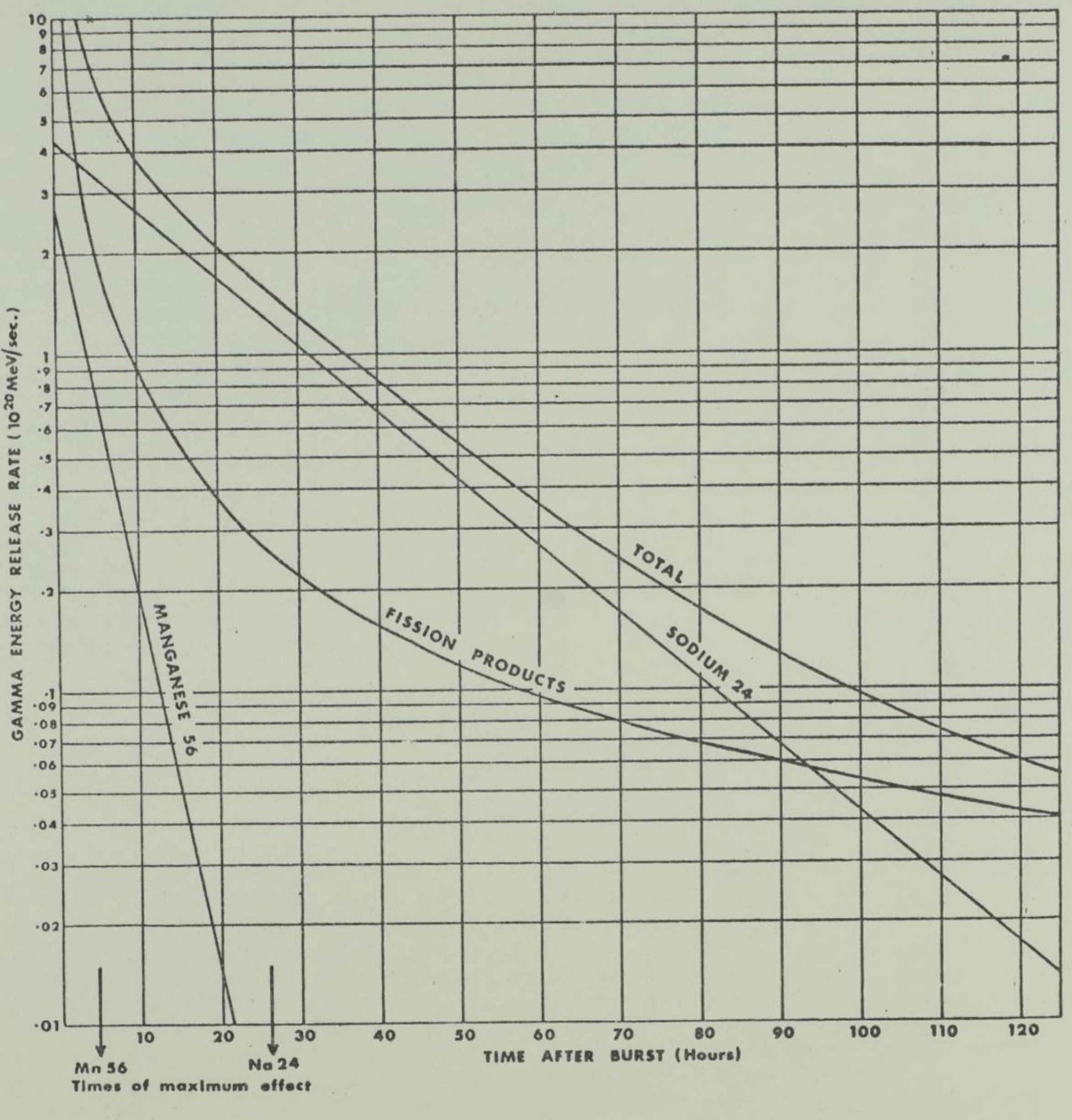
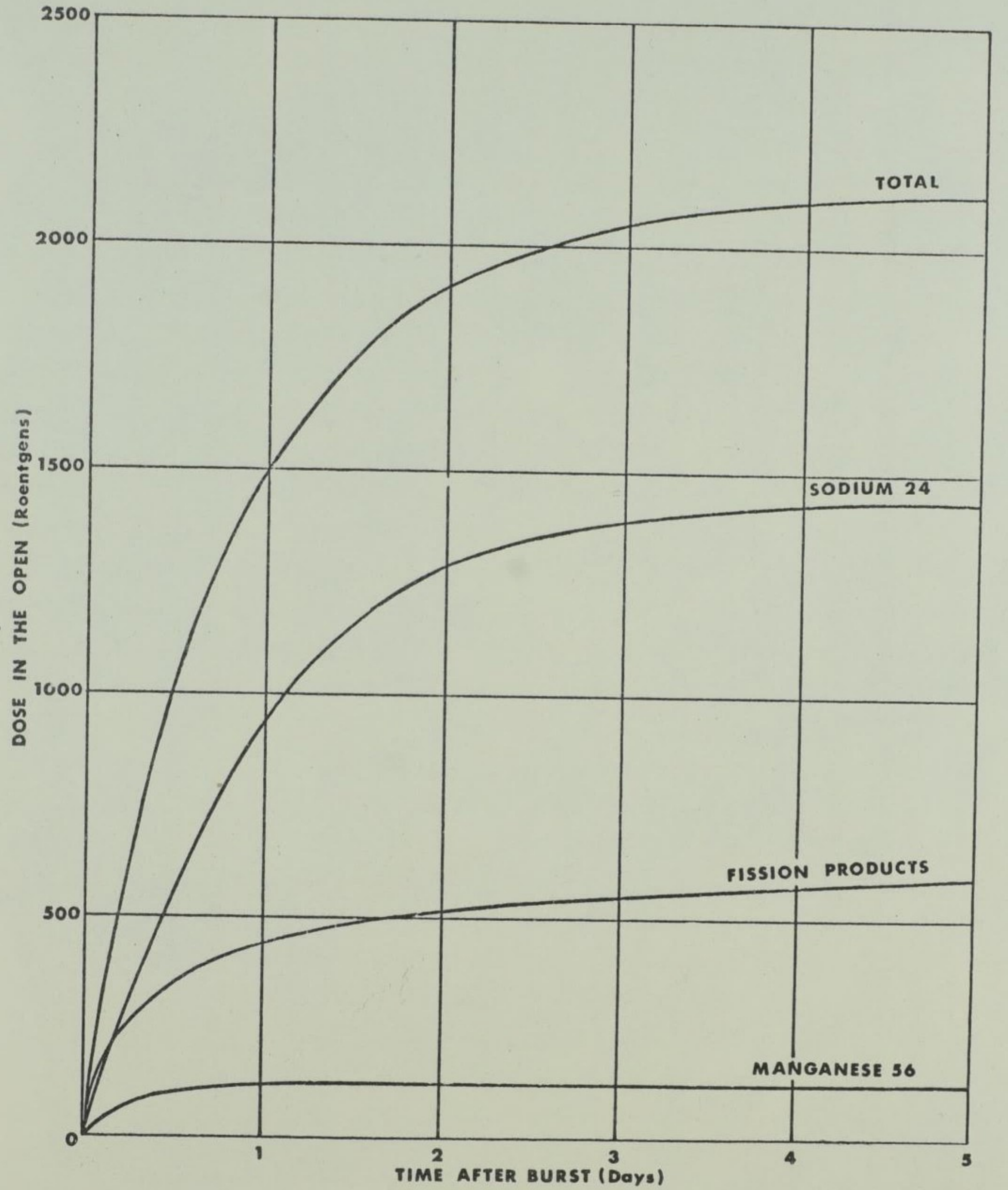


Fig. 2. Relation between accumulated dose in the open and time for a 1 megaton ground burst, 10% fission yield, 20% neutron escape,— based on a dose rate of 10 R.P.H. at H + 48 hours.



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Regional Scientific Adviser's Conference
15th-17th May 1962

The Soviet Strategic Air Threat to the United Kingdom

Mr. H. S. Young
(Deputy Director, Joint Intelligence Bureau)

Although the title of my Talk today is the strategic air threat to the United Kingdom, I thought it would be more useful to you, as Scientific Advisers to the Home Office, to talk about the strategic air threat to the West as a whole. The threat to the United Kingdom is all too easy to understand. It is, however, the threat to the West, as a whole, which determines the likelihood of war.

The Russian development of weapons since World War II falls into three natural periods. It must be remembered that, in general, Russia fought only land battles in World War II. She did not fight an air war or a scientific war, and therefore she found herself at a grievious disadvantage at the end. For the first five years of the post-war period she devoted herself to copying Western equipments, particularly those for air defence, i.e. radars and fighter aircraft. She also began building a large submarine force, but as these submarines were all of short endurance, this arm was clearly intended to play a defensive role against aircraft carriers rather than to attack our lines of sea communication. The whole accent during this period was on defence, and the only offensive items tackled in this period were the copying of the American B.29 Super Fortress, which became the Russian Medium Bomber TU4, and the outstandingly high class nuclear weapon programme which resulted in the first Soviet nuclear explosion in the second half of 1949.

The next five years may be classified as the "belt and braces" period. Russia continued to produce new marks of orthodox equipment whilst initiating research programmes on novel weapons. During this period she began research and development on guided weapons of all types, and began her work on nuclear submarines. Great emphasis was put on surface-to-air guided weapons, and this again emphasises her defensive outlook. Her first heavy bombers - the Bear and the Bison - appeared during this period. This was the first indication of a strategic offensive capability.

During the next six years she has been phasing out the older weapons in favour of new ones. The first ICBM was fired in the middle of 1957, and the first space vehicle was launched two months afterwards. Obviously, the Russians were very impressed by the political impact of the first sputnik and they subordinated the I.C.B.M. programme to that of sputniks and lunar probes for the next year. In the meantime, the production of heavy bombers continued at a very slow pace, and this, combined with the easy progress of the I.C.B.M., indicated that the Russians were in no hurry to develop a strategic offensive capability. Another most interesting development during this phase has been the missile submarine programme, and the Russians are devoting very great efforts to this weapon system.

The present Soviet air order of battle amounts to about 200 heavy bombers and about 2,000 light medium bombers. Taking the likely attrition rate into account, the threat that this presents to America is very small whilst the threat presented to the United Kingdom and NATO installations in Europe is exceedingly great. It is interesting to note that the number of Soviet day and all-weather fighters is about 8,000 which again emphasises her defensive outlook.

The missile threat has much the same character. The number of I.C.B.M. launchers available is probably less than 20, and there is no certainty that the Russians have any operational missiles at all. The number of intermediate range

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and medium range ballistic missile launchers probably amounts to about 300. Again, this poses a minor threat to the United States and a major threat to the United Kingdom and the NATO installations in Europe.

Bearing in mind that both sides almost certainly have an adequacy of fissile material, what does this all add up to? It probably means that the United States has a nuclear advantage of about 5 to 1. The quality of her deterrent is much higher, and there is much greater diversity. In terms of operations, it means that a Soviet first strike does not make sense, but an American first strike does. It means that Soviet strategy is:-

(a) Deterrence of the United States against cities, and

(b) Deterrence of Europe against everything.

On the assumption that the Soviets intend to continue their programme of I.C.B.M. production, they will certainly be able to have several hundreds of them in, say, five years. But it is far from certain that she intends to do this and, in view of the efforts which she is putting into her missile submarine programme, it may well be that, as with the heavy bombers, the number of land-based I.C.B.M's may remain small, and her major strategic missile threat may come from the se

During the discussion which followed, Mr. Leader-Williams said that the figures given by Mr. Young for the USSR Order of Battle did not agree with the data produced for the US Congressional Hearings. Mr. Young stated that the figures he had presented were almost certainly more recent than those quoted at the Congressional Hearings. The US now agreed with JIB's assessment. Sir Charles Ellis asked how US and USSR I.C.B.M's compared with regard to accuracy at comparable ranges. Mr. Young said that they had insufficient data on USSR weapons to make a valid comparison. Whilst the fall of missiles had been observed, one could not be sure of the aiming point. From the small amount of evidence available it appeared that the C.E.P. at operational ranges is of the order of 1 to 1½ miles. Mr. Western asked where the 57 MT weapon fitted into the picture. Mr. Young said that we were not at all clear about this. It was delivered by the Bear and it was possible that the Russians had not yet developed a missile large enough to deliver it. It could possibly have been developed for Mr. Kruschev's Global Rocket. Its use in an anti-missile missile appears unlikely. Mr. Western asked if the Russians could deliver it to targets in the U.S.A. Mr. Young said that this was not possible with the Bear unless it could be refuelled several times en route. Mr. Garrard asked whether in view of their age we ought to disregard the TU-4's. Mr. Young replied that the TU-4 is probably obsolete and is being replaced by Beagle. Dr. Ollis asked how the attrition rates vary with the different methods of delivery. Mr. Young said that the US Air Defence would take a heavy toll of the Bear and Bison. The picture might change when the supersonic bomber came into service. The attrition rate by the UK Air Defence might well be lower. With regard to the ICBM, the USSR has a huge programme of Anti-ballistic Missile defence, but there are as yet no signs that missile sites have been constructed. The US is developing Nike-Zeus, but whether this will ever get into service is another matter. Its cost will be astronomical even by today's standards. In UK we consider the decoy problem to be insoluble. Now that the weight of megaton warheads can be much reduced, there is room in the missile for more decoy equipment. Warheads can be destroyed if the defence knows the design. Conversely, if the defence is known a warhead could be designed to outwit it. The problem is thus very complex and a successful solution is likely to prove very expensive.

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REPORT OF A CONFERENCE OF THE REGIONAL SCIENTIFIC ADVISERS FOR CIVIL DEFENCE, HELD AT THE CIVIL DEFENCE STAFF COLLEGE, SUNNINGDALE PARK, 12th to 14th MAY, 1959.

October, 1959.

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Report of a Conference of the Regional Scientific Advisers for Civil Defence, held at the Civil Defence Staff College, Sunningdale Park, 12th to 14th May, 1959.

The Conference was attended by Regional Scientific Advisers in England and Wales and Northern Ireland, by Regional Directors of Civil Defence and Officers of a number of Departments. The following were present for the whole or part of the proceedings:-

Scientific Advisers

Professor G. E. Coates, M.A., D.Sc., F.R.I.C.	Northern Region
Professor W. Bradley, D.Sc., Ph.D., F.R.I.C.	North Eastern Region
Professor L. F. Bates, Ph.D., D.Sc., F.R.S.	North Midland Region
Professor D. D. Eley, M.Sc., Ph.D., Sc.D.	" " "
Professor L. Hunter, D.Sc., Ph.D., F.R.I.C.	" " "
B. C. Saunders, Esq., M.A., Sc.D., D.Sc.	Eastern Region
Sir Charles Ellis, B.A., Ph.D., F.R.S.	London Region
Emlyn Williams, Esq., B.Sc., Ph.D., F.R.I.C.	" "
G. E. Watts, Esq., M.A., Ph.D., B.Sc., F.R.I.C.	South Eastern Region
N. Pentland, Esq., M.Sc., Ph.D., F.Inst.P.	" " "
E. G. Cowley, Esq., M.Sc., Ph.D., F.R.I.C.	" " "
H. W. Thompson, Esq., C.B.E., M.A., D.Sc., F.R.S.	Southern Region
Professor W. E. Garner, C.B.E., D.Sc., F.R.S.	South Western Region
Professor F. C. Frank, O.B.E., D.Phil., F.R.S.	" " "
J. W. Cook, Esq., D.Sc., Ph.D., Sc.D., F.R.S.	" " "
Professor G. K. Conn, M.A., Ph.D.	" " "
Professor F. Llewellyn Jones, M.A., D.Phil., D.Sc.	Wales
S. T. Bowden, Esq., D.Sc., F.R.I.C.	"
Professor M. Stacey, D.Sc., Ph.D., F.R.S.	Midland Region
Professor P. B. Moon, M.A., Ph.D., F.R.S.	" "
Professor J. R. Squire, M.A., M.D., F.R.C.P.	" "
A. F. H. Ward, Esq., M.A., Ph.D., F.R.I.C.	North Western Region
Professor J. Diamond, M.Sc., Wh.Sc., M.I.Mech.E.	" " "
Professor K. G. Emeleus, M.A., Ph.D.	Northern Ireland
Professor H. B. Henbest, B.Sc., Ph.D., D.I.C.	" "

Regional Directors

Major General S. Lamplugh, C.B., C.B.E.	Northern Region
J. R. S. Watson, Esq.,	North Eastern Region
Rear Admiral A. D. Torlesse, C.B., D.S.O.,	North Midland Region
Rear Admiral W. L. G. Adams, C.B., O.B.E.,	Southern Region
Major General J. S. Lethbridge, C.B., C.B.E., M.C.	South Western Region
Major General R. B. B. B. Cooke, C.B., C.B.E., D.S.O.	Wales
Air Marshal Sir Lawrence Pendred, K.B.E., C.B., D.F.C.	Midland Region
Lt. General E. N. Goddard, C.B., C.I.E., C.B.E., M.V.O. M.C.	North Western Region
Lt. General Sir Alexander Cameron, K.B.E., C.B., M.C.	South Eastern Region
Captain K. L. Harkness, D.S.C., R.N.	London Region

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Sir Charles Cunningham, K.B.E., C.B., C.V.O.
General Sir Sidney Kirkman, G.C.B., K.B.E., M.C.
Major General S. F. Irwin, C.B., C.B.E.
J. S. Paterson, Esq., C.B.E.
Lt. Colonel A. J. Batchelor, M.I.Mun.E., M.Inst.H.E.
K. P. Witney, Esq.
R. H. F. Firth, Esq.
M. G. Russell, Esq.
Major General F. R. G. Matthews, C.B., D.S.O.
Air Commodore C. J. Luce, D.S.O.
Surgeon Captain J. G. Holmes, O.B.E., M.A., M.D., R.N.(Retd.)
H. K. Black, Esq., B.Sc., Ph.D., D.I.C., F.R.I.C.
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Ministry of Home Affairs, Northern Ireland

Captain C. C. McCreight, M.B.E.

Home Office, Scientific Advisers' Branch

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G. R. Stanbury, Esq., B.Sc., A.R.C.S., F.Inst.P.
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T. Martin, Esq., M.Sc., D.I.C., F.Inst.P.
A. M. Western, Esq., M.A., B.Sc.
A. D. Perryman, Esq., B.Sc.
E. Hutchings, Esq.
Miss H. Duddy

PROGRAMME OF THE CONFERENCE

Tuesday, 12th May

	Conference Assembles	
20.30	Introduction by the Under Secretary of State	Sir Charles Cunningham
	Science and Defence, past, present and future	Sir O. Wansbrough-Jones

Wednesday, 13th May

09.30	Welcome by the Commandant	Major General F. R. G. Matthews
09.35	Opening Address by the Chief Scientific Adviser	Dr. R. H. Purcell
09.45-11.00	Working Party on the Operation of Scientific Teams at Region and Below.	
	(i) Introduction of the First Report on Operations at Regional level.	Dr. R. H. Purcell
	(ii) Discussion of the Report by Regional Scientific Advisers and Regional Directors.	
11.00-11.20	COFFEE	
11.20-12.20	Part III Training of Scientific Intelligence Officers	
	(i) Regional Courses and Exercises based on the Easingwold Course.	Mr. T. Martin
	(ii) Local Authority Exercises, Exercise "Arc".	Mr. E. Leader-Williams
12.20-12.45	Summing up of the morning's proceedings by the Director General	General Sir Sidney Kirkman
	LUNCH	
14.15-14.35	Radiation Tolerance Doses in Civil Defence. Position reached since the last Conference	Mr. G. R. Stanbury
14.35-15.15	Deployment of Civil Defence Forces in relation to Radio-activity.	Mr. E. Leader-Williams
15.15-15.45	The Operational Implications of Serial 8	Mr. K. P. Witney
15.45-16.15	TEA	

Wednesday, 13th May (contd.)

16.15-17.10	Study "Pikadon". Presentation of the position at Sub-Region at H + 2 and H + 4 following a $\frac{1}{2}$ M.T. bomb on Newcastle.	Staff College
17.10-17.45	Discussion of Serials 7 - 10.	Mr. G. R. Stanbury to open

Thursday, 14th May

Scientific aspects of the Problem of living in an area contaminated by Radio-active Fall-Out.

09.30-10.00	(i) Survey of Protection against Fall-Out afforded by Houses and other Buildings.	Mr. D. T. Jones
10.00-10.30	(ii) Radio-active Decontamination.	Dr. J. McAulay
10.30-11.00	(iii) Discussion on Serials 12 and 13.	
11.00-11.30	COFFEE	
11.30-12.15	(iv) Food and Agriculture	Mr. G. Wortley
12.15-12.45	(v) Food Monitoring	Brigadier J. A. Mullington
	LUNCH	
14.15-15.00	(vi) Discussion on Serials 15 and 16.	
15.00-15.45	Fire Problems after a Megaton Explosion Study "Torquemada".	Mr. G. R. Stanbury
15.45-16.00	Conclusion	
16.00	TEA. Conference disperses.	

NOTES OF THE PROCEEDINGS

Tuesday, May 12th 1959

I SIR CHARLES CUNNINGHAM introduced Sir Owen Wansbrough-Jones and expressed the pleasure of the conference at having him to give an opening address. All those present were looking forward to hearing him.

II SIR OWEN WANSBROUGH-JONES gave his address on Science and Defence, past, present and future, which was followed by an informal discussion.

Wednesday, May 13th

III The Commandant, (MAJOR GENERAL MATTHEWS) welcomed the conference to the Staff College. He said that he and his staff were always glad to have the Regional Scientific Advisers, and regarded their annual meeting as one of the most important events of the year.

IV DR. PURCELL thanked the Commandant for his welcome and emphasised the valuable contributions to Civil Defence that had been made by the Staff College. The success of earlier Conferences of R.S.A's had been due in no small measure to the pleasant and ideal surroundings which Staff College had been able to provide.

The first Conference was held on the 16th and 17th April, 1951, and it was interesting to note that there were ten people in the room who had attended this first meeting. The above number included five R.S.A's who had served Civil Defence continuously during the intervening years. The records of the Conference made no mention of the scientific or technical matters discussed and implied that this matter was too secret to record on paper. However it is stated that the Conference was a success and this fact is confirmed by the recollections of some of those who attended although, even they, could make no suggestions as to the titles of the papers considered.

In this direction at least there has been some improvement since 1951. Relaxation of security rules have enabled summaries of the proceedings to be circulated. On the other hand there is still some difficulty because of security which certainly limits the free circulation of technical papers to scientists in the Civil Defence Corps - particularly the S.I.O's. You will all have followed in the newspapers the changes in American law pertaining to exchange of atomic information; you are probably wondering what effect this has had so far as Civil Defence is concerned. It is understood that a large number of American papers have recently been made available to the U.K. although practically none of them have any direct connection with Civil Defence. Such data will be exchanged later as a second step and it is possible that we shall shortly obtain full and complete accounts of the American experiments in Nevada regarding the effects of explosions on structures, etc.

Unfortunately the shortage of staff in the Scientific Advisers' Branch persists and there will be little time available for the critical examination of any influx of new data. Even two or three efficient recruits would make a great difference to the service that the Scientific Advisers' Branch is able to provide. A rare type of individual is required as, although research programmes are prepared and progressed, no actual experimental work is undertaken. The men should have some experience of nuclear or defence problems or, alternatively, in a parallel field which would enable the new material to be learned quickly. Additionally the men must be capable of developing a real interest in the problems of defence against nuclear weapons. R.S.A's were asked to remember this requirement.

DR. PURCELL went on to say it must be clear to everyone that while the ban on weapon tests continues as a result of the Geneva talks, there must be considerable interference and delay with plans to solve our problems experimentally. If, as everyone hopes, the ban on nuclear explosions continues, the need for critical evaluations of the older and often fragmentary data is emphasised. It will

provide the only check points for results from small model experiments using conventional explosives or from shock tube experiments. Progress in settling our remaining problems will necessarily be delayed, but this is a small price to pay for the assurance that world wide fallout will begin to disappear instead of increasing as it has done in recent months. In truth, most of the scientific information needed to solve immediate civil defence problems is already available. Although one may dispute over details in the American "Effects of Nuclear Weapons", and although there may be minor errors, this text book alone is adequate for many purposes. The present problem is to be sure that such unclassified information is fully used and that Controllers at all levels are able to apply the information to civil defence operations. Already some R.S.A's have given considerable thought to this problem and have devoted time to exercises where the scientist and Controller have attempted to work together and explore their joint problems. This mornings discussions are concerned with this type of co-operation and the Director General has consequently invited the Regional Directors to attend.

V DR. PURCELL introduced the First Report on the Operation of the Scientific Team at Region. The Report was discussed under a series of headings:

(i) Detail to be shown on the Plotting Screen. Dr. Thompson said that in the Southern Region they had found it best to reduce the map on the screen to a bare outline - the boundaries of the Region, the coastline and a few principal towns as reference points, with of course the R.O.C. posts, a network of groups of three, showing through from the back. Personally he still found the plotting screen a little harder to work with than the older light boxes. Professor Black agreed that the amount of detail should be reduced to a minimum. The function of the screen was the production of contours. Any preparation or calculations were best done elsewhere, using a separate Ordnance Survey map or a transparent overlay if necessary. An important point on the maps was to make the grid lines and references more prominent and easier to read.

PROFESSOR SQUIRE thought that main roads were important as a means of identification in an area such as that around Birmingham and Coventry. Regions in the centre of England have no coastline to assist recognition. In the subsequent discussion a considerable difference of opinion was apparent on the value of roads. Some speakers advocated a minimum number of main roads; and the suggestion was made that the system might be varied with advantage from region to region; but Professor Diamond expressed the view that, whatever system was eventually decided on, it was highly important that it should be the same in all regions. There should be a uniform procedure for the whole country. Others agreed with this view. Professor Coates asked if it would be possible for Scientific Advisers to see proofs of the maps which were recommended and Dr. Purcell said he would try to arrange this. He thought the views expressed could be summed up as being in favour of a minimum of detail on the plotting screen with, on the whole, a majority against the inclusion of roads.

(ii) The Circulation of Fall-out information within the Regional Headquarters

PROFESSOR BLACK said the problem was how to transmit to the various operational users exactly what the Regional Scientific Adviser wished them to know about the situation. This might not be an exact copy of the R.S.T.O's plot; the R.S.A. must decide what information it was proper to put out as reasonably certain. Two methods had been tried. First, the circulation of traces on flexible plastic on a $\frac{1}{4}$" scale which was carried round, and second the transmission of the information by means of grid references written on ordinary message forms.

With the first method, a considerable number of each trace is required, and copying, even by mechanical means, is a slow process; moreover the war room becomes extremely congested with people carrying round large rolls of tracings.

Then there is the difficulty of making sure that what you send round is adequate for correcting the existing traces. It is a question not only of what should be added but what should be taken off. This is a difficulty with both methods, but particularly with the tracings. Then of course the method requires that everyone must work to the same $\frac{1}{4}$" scale.

The alternative scheme of messages giving grid references for the contours which are read off from the plotting screen causes much less interference at the screen itself. The message goes to a Banda duplicator, the ten copies or so required can be run off very quickly and carried round much more easily. Moreover the messages can be sent over a telephone line. There is however the possibility of mistakes in the messages and in the plotting which must be done by the user from them. Professor Black said that on balance he favoured the grid or message system. A check for inaccuracies could be kept by maintaining a plot from the messages in the R.S.A. room.

A Speaker: How does the system work with overlapping plumes?

PROFESSOR BLACK: You do not normally send out overlapping plumes to operational users. The trend is to send out the 10 R line, and to do so you take a trace and lay it on a table away from the screen and work out the grid references from it. One of our people hit on an extremely good method with these overlays for tracing. The two top screws of the four holding the two sheets of perspex together in the frame were replaced by two longer screws sticking out in front. Then the perspex overlay was drilled with two holes and positioned on the screws.

PROFESSOR DIAMOND. I was wondering if the method of taking a photograph of the map and enlarging it afterwards would be practicable.

PROFESSOR BLACK. I expect it could be done but it is almost certain that a direct photograph of the frame would not give you what you wanted to transmit. You would have to take a tracing first and photograph that.

SIR ALEXANDER CAMERON. We have not tried the grid reference system yet, but the users are mostly unaccustomed to map references and find them rather frightening. At our last exercise we solved the problem of tracings by producing six copies of the talc tracing on tracing paper with carbon sheets, and we think that is the best method so far. Speaking as a Controller, I like to have a picture. I can see immediately if there are any changes which interest me whereas the messages have to be interpreted first.

ADMIRAL ADAMS. We used the message system at Cloud Dragon. We had all the Ministries operating, the plotters were trained by us beforehand for them, and there was no difficulty whatever. Another point must not be overlooked, that the information must be passed down to lower controls, and this must inevitably be by grid reference.

DR. PURCELL. Both methods call for training in interpretation. The scientist must remember that the other poeple do not see as clearly as he does and must bear in mind the errors which are likely to be made by the user.

ADMIRAL ADAMS. One of the surprising things we have found is reading the scientist's handwriting. It presents a major problem.

PROFESSOR BLACK. There has been a sort of feeling that message writing is not important, although it may seem a little undignified we have to face it. It really is very important that scientific people should know how to fill in a message form for duplicating and accustom themselves to systematic message writing.

(iii) Information to be supplied by Region to its Sub-Regions and Groups, and vice versa

MR. WESTERN. As regards the information to be sent down, two main methods have been proposed. First, there is the simple one that Region takes the information received from Sector, primarily referring to R.O.C. posts, and sends it

down raw, so that any given Group will receive information from the R.O.C. posts within its territory and within an area ten miles round. The second method has been used by various regions, particularly the Eastern. The messages sent to the Controller are sent out to all subordinate controls, so that there is no additional message writing, and each subordinate gets the picture over the whole Region.

There is the general question of why the lower controls want the R.O.C. information when of course they are getting information up from the Wardens. There are two main reasons. The first is in case they get nothing up from the Wardens Posts, and the second that the R.O.C. information from Sector post by post will probably be better and more reliable. The main thing is to get the information down to your subordinates as quickly as possible.

The method of transmitting the information has already been discussed, but I think it inevitable that if you send contours you lose a lot of fine detail. Contours will be accurate in some places and less accurate in others and you will not know where. Then there is the problem of reconciling the contours with the information from Wardens' Posts which the lower controls will want to do. On the whole, my conclusion is that if communications permit you should send down to your Sub-Regions and Groups the best information you have got, which is the raw data.

D.R PURCELL. I think the key words are "if communications permit". Would anyone quarrel with Mr. Western's conclusion, subject to this?

MR. WATSON. I think it is wrong to limit the information about nuclear bursts to those affecting the Region or within fifty miles of it, as you propose to do. At Region you want full information for the whole country.

MR. WESTERN. At Region you really get this from the bomb bursts, but Sub-Regions and Groups will only get those bursts which are within 50 miles of Region.

SIR ALEXANDER CAMERON. I do not think we want so much at Region. In Cloud Dragon we were inundated with bits of paper reporting bursts which really did not affect us. We could get all we want from an intelligence report once a day.

MR. WATSON. I do not agree. We filed the messages automatically, and recorded the bursts in coloured chalk for those which affected us and the rest in white; but we knew they were there.

PROFESSOR SQUIRE. Quite often it seems to me the traces drawn at Region have to be based on an interpretation process, discounting false reports, and there is the difficulty that, if you do not transmit this plot to Sub-Regions, you may have Region and Sub-Region working on entirely different plots.

ADMIRAL ADAMS. Regional Scientific Advisers must be in direct touch with their neighbours, and will get information about bursts outside their own Regions which other people will not necessarily get. This added information must be incorporated in the Regional plot and should be passed on. I would support a plot.

SIR CHARLES ELLIS. We have not talked about dependability of the information or how much error there may be in it. I would have thought it important to consider this.

MR. McDONALD. You should not order your communications so that you can only handle the material in one way, because you may want to handle it in a different way. If communications really get tight you will certainly have to do it by contours; but so long as Sector is producing information why deny it to your subordinates.

DR. PURCELL. I think this question of accuracy and dependability is important and the Working Party might have another look at it.

(iv) Direct transmission of R.O.C. information from Sector Operation Centres to Sub-Regions and Groups

MR. FIRTH. It is possible that either Regional Headquarters or its communications may suffer in a nuclear war, and in that event it seems to me we should consider what information, if any, we should try to get out from Sector to Sub-Regions and Groups. Another point is whether, even when communications hold and Region is intact, there is any advantage in passing information direct. We on the monitoring side want to help Regions and Sub-Regions as much as possible, but there are certain factors involved - manpower, space, communications and money. If we are to put in a lot more communications and have more people working at Sector we shall have to justify ourselves very fully or the Government will not give us the money.

Part III. Training of Scientific Intelligence Officers

VI. MR. MARTIN spoke on the Regional Courses and Exercises based on the Easingwold Course. He said:

I would like to draw your attention to the fact that T. Division, in consultation with ourselves, have got out a new memorandum summarizing the present position regarding the training of the Scientific Intelligence Officers. We shall circulate the memorandum and in the meantime there are some copies on this table if you would care to pick them up.

I would remind you that the training of the Technical Reconnaissance Officers, as they then were, started some seven or eight years ago with a Part I Course at the Civil Defence Schools, followed by a Part II Course given at the University in the Region and run by the Regional Scientific Advisers. There have been some changes since then. Many of the candidates had difficulty in finding time for the two courses, and the Part I training is now given locally under Regional control. The arrangements vary from Region to Region. Very often the Part I and Part II are run consecutively at the University and that seems in many Regions a very satisfactory way of doing it. I would remind you that we do not lay down any hard and fast syllabus for the Part II Course, and although this is a point on which there is some difference of opinion, we in Scientific Advisers Branch hold the view that we prefer to leave the content of this course to the discretion of the Regional Scientific Advisers.

The new features in the training of the S.I.O's is the Part III Operational Training. As you know this is given at the Easingwold School, and the courses are put on about five times a year. I think it is fair to say on experience up to the present that the experiment has been a considerable success. The S.I.O's who have attended so far have been rather handpicked; they enjoy the courses and seem to get a good deal out of them. There are however at the present time about 1,300 trained S.I.O's in the country, and recruiting is going on. Numbers are increasing, and it is obvious that, with five courses a year taking about thirty people at each, we shall not get through them very quickly. It is therefore necessary to snowball this training and we are trying to encourage courses in the Regions to pass on what is given at Easingwold. We think, generally speaking, it is best done in two stages, first an explanatory course arranged by the Regional Directors and Scientific Advisers, and later exercises conducted by the Local Authorities under the "Exercise Arc" Scheme. Mr. Leader-Williams will be talking later about this.

I would like you, if you will, to look through the T. Division memorandum to see where we stand on the question of training the S.I.O's, and to say that we do attach the greatest importance to this Part III training in the Regions. It is obvious that all the S.I.O's will not be able to get to Easingwold for a very long time.

PROFESSOR STACEY. Could you say what part the Regional Scientific Training Officers are taking in this, because they are the key men.

MR. MARTIN. We are very anxious that all the Training Officers should go through the Easingwold course as early as possible and because of this have put on specially for them an extra course in September of this year. About twenty-four of them have already been nominated.

PROFESSOR STACEY. Unless you are very careful you are going to cut them out. Some have already been to Easingwold but not many. Then you have dropped the course at Sunningdale which was one of the great uplifters of their morale.

Mr. Martin. You mean the Physics Lecturers course we put on in July 1957. We could have such a course again if it is proved to be necessary.

PROFESSOR STACEY. May I put in a plea for this. I think it is terribly important to train these men who work for us.

DR. THOMPSON. There is no doubt that all those who went to the Physics Lecturers Course were extremely pleased with it and it helped to raise morale. On the other hand the documents which are sent out for the Easingwold course are such that, on reading them, the Training Officers are able to take on this Part III work themselves. That is what is happening in our Region. We have had two such courses, one at Oxford and one at Southampton and on each occasion we called in four or five of the Training Officers who shared the lectures. We managed to get the Regional Director to provide six mobile vans for us. In each of these we had a plotting board, and with three or four people in each van we conducted the exercises full scale, thereby training twenty S.I.O's.

PROFESSOR STACEY. It is very important to keep the Training Officers at least one jump ahead of the S.I.O's. There is some danger of training the S.I.O's to a higher level.

MR. WESTERN. The printed papers are a very pale reflection of the actual course at Easingwold.

COL. BATCHELOR. We have tried to get the Regions to send the R.S.T.O's, but it is often difficult to persuade them.

MR. MARTIN. Of course the Easingwold course is purely an operational training course. The Physics Lecturers Course took wider ground, and it may be it is more suitable for the R.S.T.O's.

PROFESSOR STACEY. I feel they should be kept ahead; they should have a course or a conference which is not given to the S.I.O's.

DR. PURCELL. I have noted Professor Stacey's point and we will try to meet it. It is not quite as easy as it sounds because these courses do take up a large amount of staff time, and they cannot be put on at a few weeks notice; but we may be able to do something in the autumn.

VII MR. LEADER-WILLIAMS spoke on Local Authority Training and Exercise Arc (Area Radiological Control), a paper on which had been circulated. He said:

First of all we realised when we laid on the Part III Course at Easingwold that it was not much good holding it if we did not get a chance to practice, and the effort of organizing local exercises is fairly great. So we decided to devise an exercise which could be got out to Local Authorities and which they could lay on themselves to keep our Easingwold trained S.I.O's in practice. Secondly the realisation came home to me very forcibly indeed at Four Horsemen that until one had got people, Control side and Scientific side, reasonably well trained and practiced in working together, we couldn't really hold a useful exercise or draw any useful conclusions.

The third reason was the new ideas we developed last year at Exercise 'Pikadon', which I shall be telling you more about this afternoon, and which introduce new ideas in plotting. Controllers would need practice in these new techniques and methods of deployment, so we devised what we hope is a standard exercise, or series of exercises actually, which can be mounted by Corps Authorities at area level to give the headquarters' team, the S.I.O's and the Controllers practice in working together. Well now, what does the material supplied amount to. First of all we provided a plot - I think you have all got copies of this circular. It is a standard plot - a 2 Megaton Bomb - and it is rather a subtle plot in that its dimensions vary in different directions. It is an Area exercise. An area normally is a slice of cake, so because we have got this plot very unsymmetrical, you can get several totally different exercises by different orientations of the plot on the map of an Area. Another feature of interest in this plot is that in one place there is an interesting corridor of light radio-activity, which might make a very advanced exercise perhaps - heavy radio-activity on one side, light on the other, and a corridor around Ground Zero.

The plot is drawn on a grid, and for each point on that grid, we have prepared and listed in the exercise papers which you have already got, the radiological history of that grid point. The following are given for each grid point:-

> the dose rate at 1r; the time of arrival of fall-out; the time of fall-out maximum; the reading at F.O.M.; the time of completion of fall-out; the reading at F.O.C.; and the dose rate at 7 hours,

so that what anybody mounting this exercise has to do is to superimpose the fall-out trace on to a map of the Area. You have got here the Halifax area. On the Area map the Wardens Posts are of course marked and you can get therefore from these schedules the radiological history of each Warden's Post by assuming its history is the same as that of the nearest grid intersection. It is a comparatively simple matter therefore to get a radiological history of each Warden Post in this Area.

One point we recommend in setting this exercise concerns communications. Clearly the position of an Area is very different according to whether communications survive or not, and for interest and practice, it is probably a good thing to assume in an exercise that communications from two or three of the Sub-Areas have survived and that two or three have failed. Where communications survive of course, then appropriate messages can be prepared by the Setting Staff from the tables and fed in, giving the radiological history for each Warden Post.

Where the communications fail information can only come up to Area by Recce. and that is where the Directing Staff come in. They have to follow the routes along which recce parties are sent out by the Controller and prepare and send back appropriate messages. We found in practice that one S.I.O. on the Directing Staff cannot cope with more than about two recce. parties, so that the number of recce. parties which the Controller can send out must be limited by the number of S.I.O's on his Directing Staff.

Another thing you should know about this exercise is that we have speeded everything up a bit; the winds are fast and the fall-out maximum is rather sooner than you would expect in real life in order to get the exercise over in a reasonable time. It is planned to run about four hours. Before we produced this and sent it out, we did of course play it over in S.A.B. to see how it worked. We gave instructions and the overlay to one of our assistants of about S.I.O. quality who had not been concerned with this sort of work - gave him this and he started from scratch and synthesised the material. Actually Dr. Purcell acted as an Area S.I.O. and plotted material coming in. We found the exercise ran through quite well, but it took a completely inexperienced man two or three days to prepare the necessary messages and plots.

VIII THE DIRECTOR GENERAL (SIR SIDNEY KIRKMAN) summed up the morning's proceedings. He said he wished to emphasise the value of exercises; it was only when one actually tried out some technique under conditions as realistic as possible that one could say if it was satisfactory or could be bettered. In Cloud Dragon mistakes were made by the Royal Observer Corps, partly because the technique was comparatively new to them, but we must expect that some mistakes would always be made. Cloud Dragon may have seemed to go rather slowly, but he was sure that those who had taken part would agree that they had benefited by it.

The Director General said that in considering the tempo at which an exercise seemed to go, it was important to remember that the urgency of information would vary according to the level of the headquarters concerned. The Regional Commissioner would be looking well ahead, thinking perhaps whether he should deploy all his forces, or whether he should keep reserves in hand to help deal with further bombs which might come; he would be thinking of tomorrow rather than today. At Sub-Regional and Group level, the Controller would probably be thinking of the one bomb he already had to deal with, but even so he would perhaps be thinking primarily of to what extent he should conserve the radiological lives of his forces. Both at Regions and Sub-Regions the staff would be working on small scale maps, say ¼ inch. At Area level and below Controllers should be thinking of what should be done now, and they would be impatient for information. They would be working on larger scale maps, say 1 inch or 2½ inches.

As regards maps, the Director General said that Scientists must make up their minds whether they should maintain one fall-out map or two; it might be that the actual plotting was best done on a map with no more than the national grid and the sea, whilst discussions with Commanders of the various forces were carried on over a second map, showing essential detail, maintained alongside the first. Decision could only be made as the result of further trials.

The Director General said that another problem as yet not satisfactorily solved was how to distribute fall-out information round a large headquarters. Messengers walking around with tracings was a slow and primitive method liable to errors, and in the end the messengers became exhausted. He went on to emphasise the need for a common doctrine. In the event some people would depart from a doctrine, but it was none the less necessary to have one, and to have it in writing. At present S.I.O's had to go to Civil Defence Schools to learn; it would be better if in the first instance they could study problems of the types which had been discussed in books or pamphlets. This was the Home Office policy.

The Director General ended by referring to the value of Scientific Conferences; only if we discussed our differences could we arrive at a common doctrine.

IX MR. STANBURY summarized the position reached since the last Conference in regard to Radiation Tolerance Doses in Civil Defence. He said:

Last year, at this conference, we introduced you to a new table of radiation effects which had been compiled by Dr. E. Alpen of the U.S. Naval Radiological Defence Laboratory, and had been made available to the armed services of both countries as a basis for building up a doctrine of radiological protection under conditions of nuclear attack. For convenience, this table is reproduced here:-

Dose in 4 hrs. (roentgens)	Effect
Up to 150	No acute effects - increasingly serious long term hazard.
150 - 250	Nausea and vomiting within 24 hours, minimal incapacitation after 2 days.
250 - 350	Nausea and vomiting in under 4 hours. Sympton free period 48 hours. - 2 weeks. Some mortality will occur in 2-4 weeks.
350 - 600	Nausea and vomiting in under 2 hours. Heavy mortality certain in 2-4 weeks. Incapacitation prolonged for the remainder.
600	Nausea and vomiting almost immediately. Mortality in one week.

After very careful consideration of the way in which this Table could be used in civil defence, it was decided to recommend to the Medical Research Council that we adopt a "Wartime Emergency Dose" of 75r.

It was realised that while every effort must be made to reduce all radiation exposure to a minimum because of the harmful long-term effects, this could not be a major consideration in fixing the acceptable dose for civil defence personnel engaged on urgent life saving operations.

The decision to adopt 75r rather than 150r - the minimum dose for acute effects (radiation sickness) - was made chiefly because it provided a factor of safety of two to allow for errors in instruments; variations in radiation susceptibility between individuals overrunning of the dose either by accident or design because of the urgency of the operation; and of course for keeping long term effects as low as feasible.

There were also some operational advantages in sticking to 75r. If the dose was pushed up to 150r it could be used either

(a) at twice the dose rate for the same time (i.e. at 20 r.p.h. for an 8 hour shift instead of 10 r.p.h.) or

(b) at the same dose rate for twice the time (i.e. at 10 r.p.h. for 16 hours).

In both cases the return in numbers of people rescued alive would not be proportional to the increased dose. Working at higher dose rates would incur working closer in where the damage was greater and the chance of survival less, and working for twice the time would mean that the return in the second 8 hours would be smaller than in the first 8 hours because of the known fall-off in the return of people rescued alive with time after being trapped. [Mr. Leader-Williams had assumed in "Picadon" that the chance of recovery alive fell linearly to zero at 48 hours.]

This proposal for a wartime emergency dose of 75r had been considered by a meeting of the appropriate M.R.C. Committee in early December 1958, and no serious objection was voiced to it. They feel that everyone concerned with the problem should be taught to understand that all radiation exposure is harmful and should be kept to a minimum consistent with the importance of the operation envisaged.

It is now proposed that the 75r wartime emergency dose should become part of civil defence policy, the dose being used up over 8 hours at a maximum of 10 r.p.h. (the old "red line"). The old "green" line of 3 r.p.h. seems to serve no further useful purpose and it is proposed to abandon this conception on civil defence planning.

X MR. LEADER-WILLIAMS introduced a paper entitled The Deployment of Civil Defence Forces into Damaged Areas Contaminated by Fall-out (CD/SA 92). The paper had been circulated to all Regional Scientific Advisers before the Conference.

XI MR. WITNEY said that the administrative decision to confine the Wartime Emergency Dose to 75r. had been taken in the light of the considerations already described by Mr. Stanbury and Mr. Leader Williams, and also of one other consideration of importance, which was that whatever planning dose was accepted some margin had to be left for it to be exceeded at discretion. He went on to define the discretion to be permitted, which was of two kinds; a strictly limited discretion to unit commanders in the field to allow the dose to be exceeded up to a maximum of 100r. in order to complete vital work in the absence of reliefs; and a larger discretion vested in the Regional Commissioner to increase the dose for all or any of the forces engaged. It had been thought right to confine this larger discretion to the Regional Commissioner because it was essentially a matter of weighing long-term "survival" considerations against immediate operational needs, and therefore could not fairly be left to any Controller, however senior, whose responsibilities were primarily operational.

Subject to this, the Wartime Emergency Dose had been agreed with all services and departments having operational responsibilities, including the Army. It would, of course, apply only to life-saving operations conducted under civil defence control; but it had been accepted that it would be quite wrong for different services engaged jointly in such operations to be made subject to differing degrees of radiological hazard. It had also been accepted that the dose should apply to operations in undamaged as well as damaged areas, e.g., to "Z" zone clearance; and to members of the public as well as the uniformed services assisting in such operations, e.g. to stretcher bearers, bus conductors working in a "Z" zone, or plant operatives clearing debris.

The 10 r.p.h. (Red) line had been agreed as the basis for planning for the operations of the casualty services. According to the nature of the work other services might find it more profitable to work for shorter or longer periods at higher or lower dose rates. Particular cases would have to be examined. Such an examination was already being undertaken in respect of reconnaissance, and it was hoped that it would shortly be undertaken in respect, e.g. of fire-fighting and police control of the homeless.

The principle of estimating the tasks uncovered by the Red line over successive periods of time, and of matching resources to it, had also been accepted, though there was some disagreement (in no way affecting the principle) on the probable output of the forces, in particular of Rescue Parties. It was hoped by field trials to reduce the margin of disagreement. It was also hoped to carry the application of the "Pikadon" principles further; for instance, by relating the output of casualty collecting parties with the capacity of ambulances and Forward Medical Aid Units so as to arrive at a standard "casualty unit" which would enable casualties to be cleared without accumulation either at ambulance loading points or at the F.M.A.U. It should be noted that recent exercises and studies had all tended to suggest that the major limitation to operations would be an acute shortage of ambulances.

There were other points on which the "Pikadon" conclusions might need to be modified. For instance, it appeared that in certain cases - perhaps the majority - the effective limit of operations would be set, not by high radioactive intensities, but by impenetrable fire or debris. Account would have to be taken of that, but no necessity could be foreseen for any major departure from the "Pikadon" conclusions.

XII The STAFF COLLEGE presented two playlets from Study "Pikadon" illustrating the position at Sub-Regions at H + 2 and H + 4 following a ½ Megaton bomb on Newcastle.

DR. PURCELL: I am sure you will wish me to thank the Staff College for giving us these presentations. In the Branch we thought that it was interesting to put them on, not only for the subject matter they contain, but also to get your opinion on the value of this type of approach. Obviously it is expensive in staff time because of the number of people engaged and the time which must be given to rehearsal. Equally I think in the Civil Defence Department it has been found it is the only way of getting this type of information across.
Dr. Thompson suggested that if you give people something on paper to read it is sufficient, but unfortunately many of our audiences do not seem to read the paper we give them, and this is an alternative.

XIII MR. STANBURY opened a discussion on the afternoon's proceedings with some observations on the subject of Upwind Fallout. The substance of his remarks has since been given in a paper entitled Upwind Fallout from Megaton Explosions, by G. R. Stanbury and A. M. Western, (CD/SA 94) which has been circulated to all Regional Scientific Advisers.

PROFESSOR BATES: It seems to me that we have not paid enough attention to the relative importance of long term hazards to young people and old people. It does not seem to me to matter very much what happens to men and women over 40 and 50, but it does matter to younger people. We should divide our Civil Defence into two teams, young and old.

DR. PURCELL: This has certainly been thought about. There are quite serious difficulties and it is the sort of thing that at present one only tells to responsible people; there has been no official formulation of policy on these lines.

PROFESSOR BATES: Does anybody know what the shortening of life is for a man of 50 compared with that for a man of 25?

DR. PURCELL: I don't think this is known, but obviously long-term effects that take a minimum of 7 years to develop are more serious for a man of 25 who has a greater expectation of life than an older man. I am sure Professor Squire can talk on this.

PROFESSOR SQUIRE: I am strongly in favour of segregation of the younger group, but I do not see at present how it can be done. There does seem to be a big gap between 75r and the peacetime exposure of 300 mr. per week, and we should all do our utmost to see that all radiation exposure be kept to a minimum.

DR. PURCELL. The philosophy at the basis of the adoption of the 75r wartime emergency dose is that we cannot avoid giving large sections of the population doses of that order, but we should still try and limit as far as possible the exposure of small groups of specially trained people. The ordinary industrial tolerance is meaningless under these conditions.

PROFESSOR BRADLEY: Is there any new hope that satisfactory radiation protection devices will become available?

DR. PURCELL: This would of course materially change the situation, but I understand that none of the drugs so far suggested have really been proved or are even very suitable for distribution as pills to the population.

PROFESSOR BATES: I was thinking more of the Civil Defence personnel

DR. PURCELL: If satisfactory drugs were available they would be extremely valuable, but to the best of my knowledge this is not the case.

PROFESSOR STACEY: Would not these figures take on a much healthier look if we had a proper system of protection on our ambulances, etc.

DR. PURCELL: I agree but protection is only achieved by incorporating extra weight into the vehicle, for example several tons into a normal baker's delivery van. We have been looking into this and have done some tests with improvised protection which are hopeful.

PROFESSOR SQUIRE: I wanted to say that I thought Leader-Williams' studies had carried us a great deal further, although the conclusions could be drawn in various ways. He has been unduly modest about the 'guess-work' involved in the assumption that people rescued early have a very much greater chance of survival than those rescued after 48 hours. Dr. Bull has now found some figures concerning abdominal injuries in the Italian Campaign as follows:-

Treated 0.6 hours after injury - 30% mortality

" 48 " " " - 90% "

with intermediate times graded in linear fashion as in Leader-Williams' assumptions. Furthermore radioactivity effects might well steepen this line and bring it even closer to the assumptions. Alternative conclusions that might be suggested include (i) the greater need for evacuation prior to disaster to make the size of the rescue problem more reasonable, (ii) the need for fully adequate supplies of vehicles like ambulances (or cars adapted to take stretchers), and (iii) possibly the redeployment of rescue services for casualty collection, by which, it seemed, the figure of 5,000 effective rescues out of a total of 60,000 casualties might be increased by a factor of 2 or 3.

DR. PURCELL: I am glad to have Professor Squire's assurance about this. It is the main thing that has been worrying us in the Branch; if this is not true, everything we have put forward is nonsense.

MR. McCREIGHT: Has anybody made an estimate of the manpower needed to rescue casualties? I was wondering if we would ever get to the stage where the Government would say that we can't afford rescue; we have to concentrate on the survival of what is left.

DR. PURCELL: That is a feasible problem to pose, but not an easy one to answer; in any case I doubt whether it would be a politically acceptable idea at the present time. The RAND Corporation in its assessment of what would happen in the United States reached an estimate of 140 million casualties out of 180 million, and when you begin to consider numbers of this magnitude then obviously this type of consideration must arise.

DR. THOMPSON: Would it be possible to make a film of the two acts we have seen for use in the Regions. I think it is an excellent way of teaching.

COL. BATCHELOR: At the present time this would not be possible as the money we have on the vote for this year is already mortgaged on two films - Civil Defence Control and Wardens. We might persuade an amateur photographer to come in and do it.

DR. PURCELL: I am sure we must look into this.

COL. BATCHELOR: At Study "Chester" - the study of debris clearance - Training Division did make a very good film, although it was done by non-professionals.

PROFESSOR SQUIRE: I think I am right in saying that there are 50,000 cars in Newcastle today. Surely it is not quite realistic to show 500 cars only as being used for carrying the injured? Are we not underestimating our mechanised potential?

MR. LEADER-WILLIAMS: We certainly may be, but a limit would soon be reached because of the time taken in giving first aid and in delivery to the ambulances.

DR. PURCELL: I would have thought that Professor Squire was absolutely right in saying that we must make more use of private motor cars to carry the injured.

DR. MURRAY: I imagine the figures quoted do not include private cars; possibly they could be used.

MR. WITNEY: We were working on that basis. The station-wagon type of car could certainly be used, and ordinary cars could be used for sitting cases.

Thursday, 14th May.

XIV MR. JONES described a Survey of the Protection against Fall-out afforded by Houses and Other Buildings. He said:

This work was begun in 1956 when the White Paper on Civil Defence (Cd 9691) called for a sample survey to be made to find the level of protection against fallout which houses and other buildings could provide. The survey of private houses was started in 1957 and has now been completed. You will have had a paper describing the results of that survey - CD/SA 89.

Private Houses. The Home Office obtained the co-operation of the Local Authorities in eleven urban and rural districts which were considered to represent typical reception areas in the country. None of the large conurbations was included: the populations in all cases were less than 100,000, in most cases considerably less. The districts were:

Carlisle, Chesterfield, Exeter, Harrogate, Kirkcaldy, Perth, Wellingborough, Wrexham, Chelmsford, Witney and St. Boswells.

The Authorities were provided with a table which gave the protective factors of typical houses. Their task was to take a census of houses of various types and render a return of the number of households having given protective factors. On the whole the results showed that factors were lower than expected. The table on page 5 of CD/SA 89 shows that many households would have factors less than 40.

The Authorities were asked to consider three possible schemes of protection. Under Scheme A householders would stay in their own dwellings; under Scheme B they could move, if they occupied part of a building such as a flat, into the best part of the building; and under Scheme C they would make use of an underfloor trench in their own premises - if this were feasible.

Some of the outstanding results showed that in rural districts 45% had factors less than 25, 40% less than 40, and 97% less than 100. For rural districts under Scheme C, the corresponding percentages were 35%, 57% and 76%. In urban districts the corresponding precentages were 31%, 57% and 90% under Scheme A, and 11%, 40% and 52% under Scheme C. Combining rural and urban districts with appropriate weighting we found 'natural' estimates under Scheme A to be 36%, 64% and 95%; and under Scheme C to be 21%, 46% and 61%. There was some improvement in rural and urban districts in Scheme B and Scheme A, but on the whole this was very slight.

In some areas it was found that the factors at the centres of towns were distinctly higher than at the outskirts. In Chesterfield, for example, there was a marked difference, but in Kirkcaldy there was not much difference.

Communal Buildings. The Survey of communal buildings, that is buildings other than private houses which could be used as shelters, was begun in November last year. There were buildings such as theatres, churches, schools, office blocks, department stores and so on, which could accommodate large numbers of people. This work is not complete, but some interesting results have already been received.

The procedure was unlike that which was adopted for private houses. The same eleven Local Authorities took part, but it was not possible to provide a table from which the protective factors of buildings could be 'read'. This was because there was no useful way of defining classes of buildings to which factors could be assigned with any reliability. The Authorities were therefore required to calculate the protective factors of individual buildings which could be available as communal shelters. If any buildings, however, obviously gave very poor protection or exceptionally good protection, calculations were not made. The former were buildings above ground of very light construction and the latter were basements with heavy material in the floors and roof.

It was not considered feasible to have calculations done for every communal building in an area as this would have laid a very heavy burden on the Authority. Instead, three squares each of a quarter mile side were selected as samples. For the urban districts, one of these squares was taken in the heavily built-up central part, another was taken from the less heavily built up surrounding zone and a third from the comparatively open zone further out where there may be a considerable number of houses but only an occasional communal building. Three squares were also selected for the rural districts to represent three orders of built-upness in these districts. The names, types and locations of the buildings surveyed were included in the return. As all calculations of protective factor were done on the assumption that door and window spaces were blocked up with material to the weight of the surrounding wall, the amount of wall areas to be blocked up was also included. This was to provide information on the amount of work and material involved.

The floor area was also given as this provided a measure of the numbers of people who could be housed. Ten sq. ft. per person is a standard of shelter space per person, and this was used in the analysis. There may, however, be acceptable variations to this space allowance.

In assessing the protective factor of a building, the dose of radiation which is received inside the building is calculated as a percentage of the dose received outside. This percentage is made up of two separately calculated contributions, one from the roof contamination and the other from ground contamination. These contributions were given separately so as to show the relative contributions from each. This separation may be used for example to assess the effectiveness of roof washing which would remove most of the roof contamination.

Each completed return gave detailed information on the distribution of protection in each square actually surveyed. To assess the distribution in the district as a whole, however, it was necessary to extend the information to cover the whole area. This was done by estimating the numbers of quarter mile squares in each district which contained on the whole a range of buildings of equivalent value to the squares actually surveyed. These estimates were made by the local authority surveyors in consultation with the Scientific Advisers' Branch. It was then possible to assess the distribution over the whole area by multiplying the value found in the sample square by the appropriate number of equivalent squares.

The results show that there are considerable differences in the various districts. This is to be expected. Towns which are centres of commerce or perhaps tourist centres, contain many large buildings which could provide good communal shelters. Most rural districts, by contrast, contain very few large buildings and the protection is poor. In more than half of the urban districts and in all three rural districts, there are not enough communal buildings of real value as shelter to accommodate the whole of the population. In urban districts the percentage with factors less than 30, for example, range from 0 to 79, while in rural districts the percentages are all above 90. Harrogate provides the best protection with only 21% having factors less than 300, while Witney has the worst.

The distribution of protective factors in private houses, reported in CD/SA 89, was found to be usch that substantial proportions of the population in all areas would have low values, for example less than 30.

Nevertheless, many private houses and communal buildings give good protection and a very considerable improvement in the general level of protection in an area could be achieved by using the best private houses and the best communal buildings.

One of the towns which shows a considerable improvement in this way is Harrogate. The chart gives the numbers of people who could be accommodated in communal shelters with factors greater than given values, and also the numbers who could be accommodated in private houses with factors less than given values. The points at which the private house graphs cross the communal graph give the minimum factor which is achieved by using only the best communal shelters and the best houses. For communals combined with private houses the minimum is about 275. This is a spectacular increase over the minimum achieved if either private houses or communals is used. In the sample of urban districts as a whole, the minimum factor, using private houses (A) and communals, is 30, while the minimum, using private houses (C) and communals, is 40. In the former case only about 30% have factors less than 100 while in the latter only 7% have factors less than 100.

Spectrum of protective factors. Surveys of this kind provide us with a spectrum of protective factors for each scheme adopted - that is the proportions of people who have protective factors of any given values under the various schemes. The form of this spectrum, together with the spectrum of radiation intensity in the open, in the event of an attack, can be used to determine the spectrum of dose received by people in protected accommodation.

A detailed analysis on these lines would have to allow for variations in type of attack, weights and distribution of attack over the country, for distribution of population and variations in meteorological conditions. It could only be undertaken with the use of computing machinery. One simple and approximate calculation however has been made to see broadly what the effect would be on the populations of urban districts. The tentative results are shown in a chart where a comparison may be made of the effect of weight of attack between one 10-megaton and one hundred 10-megaton bombs under four possible protective schemes:-

(a) Private houses (A)

(b) Private houses (C)

(c) Private houses (A) and communals

(d) Private houses (C) and communals.

The estimates which can be made from this graph are the proportions of population who would receive 200r or more during the first 48 hours after the attack. It can be seen that there are great differences depending upon the scheme of protection. For a one ten megaton attack for example the proportion can vary between one in 10,000 to 2 in a thousand. For a ten 10 MT attack the proportion can vary from one in a thousand to one in twenty.

The results of this calculation which assumes that the attacks are randomly distributed over the country and that the meteorological conditions are typical must be regarded as most tentative. The numerical results should only be taken to indicate the orders of difference in adopting the four possible schemes.

Conclusion. There is not enough shelter in communal buildings in the country as a whole to accommodate the resident population (allowing 10 sq. ft. per person). There is considerable variation between districts. Urban districts on the whole provide for better communal accommodation than rural districts. Great improvements in the general level of protection can be obtained by using the best of both houses and communal buildings. In the sample of urban districts surveyed the minimum factor becomes 40 and in rural districts the minimum becomes about 10. These are to be compared with the minimum of about 2 which is available in private houses alone. Under the best combination of communal buildings and private houses (C) in urban districts, only 7% would have factors less than 100.

If plans are to be made for the use of communal buildings, consideration should be given inter alia to the time spent in travelling from home to shelter. This is important in relation to warning time.

The protective factors may generally all be somewhat higher than calculated as recent experiments on the attenuation by structural materials tend to show that the attenuation is greater than was assumed. At the same time it is reasonably certain that the order in which buildings could be placed in respect of their protective factors will not be changed.

MR. McDONALD: How critical is the assumption of 10 sq. ft. per person?

MR. JONES: I have assumed this as what might be an acceptable standard. One could see the effect of varying the space allowance. The general effect on the combined schemes of reducing the space allowance in communal shelters would be to raise the general level of protection, and the minimum factor would be higher.

MR. LEADER-WILLIAMS: One could play with these assumptions and see what could be done.

A SPEAKER: What was the area per person in the German Bunker Shelters?

MR. LEADER-WILLIAMS: They crowded them in pretty well. The actual occupants were about 60,000, and the shelters were designed for 12-18,000.

PROFESSOR MOON: Do these urban districts include a proportion of big cities or not?

MR. JONES: We included places like Harrogate, Wellingborough, Carlisle and Exeter, and deliberately excluded large conurbations like Manchester, Birmingham, and so on. Up to date we have not had all results from rural districts, but rural districts would certainly be worse than urban districts.

PROFESSOR CONN: Have you considered factory accommodation at all?

MR. JONES: We had to leave out industrial buildings because these are being dealt with by industry itself.

SIR CHAS. ELLIS: Should not consideration be given to the time available for people to get to communal shelters after warning has been given.

DR. PURCELL: That point is still under discussion.

MR. LEADER-WILLIAMS: This is very hot from the Press, and you have got only partially analysed results. You must now look and see how you can use these results. If you are going to use communal shelters you tend to have to go a long way to them, so therefore a long warning time is required. Then you have the question - should communal shelters be occupied on the Black or the Red. If you regard them purely as fallout shelters maybe you can go to them on the Black or Grey warning; the latter gives you an hour to get there. All these are things which we shall be considering very actively over the next few months to see what sort of refuge policy we should adopt.

AIR COMMODORE LUCE: In a large scale attack there would be considerable damage to buildings due to blast, and consequent loss in protective factors. Does the graph take this into account?

MR. JONES: The curves are approximate and take only fall-out into consideration. We would have to take blast into account too especially in a very large attack.

DR. PURCELL: A very large attack is an overwhelming one, but even then there is quite a large percentage of the country affected by fall-out that has not suffered serious physical damage if you exclude window breaking. Another point is that you would have to consider not only the 48 hour effect, but whether you can live in the country during the succeeding year.

MR. LEADER-WILLIAMS: If you put the total casualties either killed by blast or getting more than 200r - making allowances for the fact that their houses will be damaged, then the position will look very different with 100 10-megaton bombs.

PROFESSOR STACEY: What are the chances of removing contamination by washing down or using a movable covering?

MR. JONES: As far as houses are concerned it is very true that decontaminating the roof in private houses would reduce the dose. In many communal buildings such as large shops and buildings with lots of floors above, roof decontamination might not make much difference.

MR. WESTERN: What about churches and cinemas? Do they make any appreciable contribution to shelters.

MR. JONES: Churches and schools are not the main contributors; Shops, hotels, public houses, banks and office blocks seem to give the best protection.

MR. WESTERN: Shops have surprisingly big windows.

MR. JONES: On the other hand a lot of them have good internal walls and basements.

PROFESSOR COATES: One lot of communal buildings seem to have very high factors.

MR. JONES: Yes, I think an interesting point is that of underground basements in large buildings. If detailed spectrum calculations are to be made, we shall have to estimate the shape of the distribution of protective factors. We appear to have a J-shaped distribution of low values with a quite distinct peak of high values which corresponds to basement protection.

SIR CHARLES ELLIS: One point I wish to raise is this. There can come a point when the dose you are protected from during the first 48 hours may make just the difference between survival or non-survival. There is then the question as to whether you wish to save the maximum number of people during 48 hours or to see that the ones you do save have enough radiological reserve to stand the next year or two.

DR. PURCELL: It is one that needs thinking about because the really attractive thing is that it may be possible for people to have a negligible dose during the early period and thus be capable of surviving and being active in the post attack period.

My own feeling is that, if you have big protective factors in buildings within a reasonable distance, it is attractive to send people to the communal shelters. On the other hand, when there is a Red or Black warning you have this possibility of being caught in the open; but it is far too early yet to suggest any policy on the use of communal shelters.

MR. WITNEY: Well, of course, all this has only just reached us, but I think there will certainly have to be an extraordinary amount of thought given to the psychological side. There are certain views on how far the public will tolerate living in communals, and that seems to be vital. My own inclination would be to send them there only on the Grey. It may be entirely wrong - but communal living seems to me to become difficult.

DR. PURCELL: Well, they are going to have to live in worse conditions.

XV DR. McAULAY gave a review of progress in Radioactive Decontamination. He said:

It is three years since we last reviewed the problems of radiological decontamination. Of the few papers which have come in the first is one from the Chemical Defence Experimental Establishment - PTP (R) 20, which gives an account of their experiments on Decontamination of Skin and Clothing. There are two American papers that you might like to study at your leisure. One of them is a paper by the staff of the Stanford Research Institute under contract to the Office of Civil and Defense Mobilisation - CD 11727 - entitled 'Systems Analysis of Radiological Defence'. The other one is a report on 'Operation Plumbbob' - American Atomic Energy Commission - CD 11605. There are two other papers that I want to refer to - one is the very voluminous report on The Radiological Recovery of Fixed Military Installations, which seems to be based on questionably high effectiveness in cleaning up surfaces. The chart shows the residual number, i.e. the activity remaining after decontamination. We are rather doubtful about all these figures and particularly about 95% clean up of a concrete road by fire-hosing. The other report is by Technical Operations Incorporated - Radiological Defence Planning Guide. This particular group was asked to produce a complete defence plan for O.C.D.M., but their work is based on the same data which appear to relate entirely to large particles from bursts on desert sand, and easy to remove by simply blowing or washing them away.

Coming to the problem of the removal of contamination from skin, clothing, vehicles or equipment, this is a secondary problem because it is difficult to imagine conditions where the radioactive dust hazard could be serious without simultaneous lethal gamma exposure. In spite of high standards of personal cleanliness you may later get a Beta burn, but it is still only a burn. The main object of decontamination of skin and clothing is to keep the Operating Theatre clean and to keep contamination from getting into wounds or into food and drink. The first problem that Porton faced was to get a suitable simulant for fall-out. They produced a simulant consisting of glass microspheres impregnated with 0.15% Ta and these were irradiated in a pile to roughly .1 mc/gm. The microspheres were 10 to 100 microns in size which is the biggest they can make. The 10 micron particle represents something much more difficult to remove from skin and clothing than the kind of particle Mr. Stanbury was talking about, i.e. fall-out particles of 75 microns and above.

Then they had the problem of getting live skin, which was difficult, so they made a skin replica by taking an epoxy resin cast and from this they obtained a positive using a solution of methyl nylon in chloroform and alcohol. The replica gave a good representation of the mechanical surface of human skin. Porton found that with particles of 10 to 100 microns, by using ordinary soap and water, they could get effectively over 98% removal. In the case of clothing contaminated with these glass microspheres they found brushing or shaking ones jacket is not a very effective way of removing these particles - less than 60% in some cases - so they tried washing with detergents. I cannot imagine anyone doing this with a suit, but with washable fabrics over 98% was removed in this way. The fabrics were placed in the tub or in a washing machine and stirred about 100 times. In the case of outer clothing they naturally felt this was not desirable so they tried vacuum cleaning and got more than 98% removal.

Before going on to the question of decontamination of areas, there is one very important piece of real factual evidence I wish to mention. If a particle say of earth - 200 microns - is sucked up into the cloud, and fission products condense on it, and if that particle gets wet coming down, the activity after about 10 minutes becomes, to a large extent, fixed in the particle. Also, if the particle comes down on to a wet surface, and is wet for 10 minutes, the amount of transfer is likely to be negligible. Except for water bursts our problem is going to be very largely a mechanical one of removing the particles from the contaminated surface.

Now area decontamination. Here we are faced with the problem of a heavily contaminated built-up area, and what to do after 48 hours. We have to decide for instance, whether it is going to be worth while to clean up

roads, pavements, roofs etc. and when we ought to do the jobs. We have not got very clear answers to this problem in spite of the voluminous reports from America. The experimental work in the U.K. is being done by Porton who have recently acquired a road sweeper and various other items of equipment needed to clean up an area. They will carry out trials as soon as supplies of suitable simulant are available.

Let me go back to two years ago. Many of you probably read the Report of the Physics Lecturers Course. There I reviewed the problem and the many factors involved on which we have no accurate data. A number of factors were combined into one Parameter:-

$$N = \frac{PX\ T_{(25)}}{2L}$$

where P is the resident population, X in feet per hour is the rate of clean up of a street, L the total street length to be cleaned, and T(25) the time in hours the operators could work before getting a dose of 25r. N represents the number of residents per operator required for decontamination. Thus if decontamination were started at 2, 4 or 6 days after the burst, the values of N would range from 185 to 370, from 500 to 900, and from 800 to 1,500. Now I assumed in doing the decontaminating that people came from outside to operate the road-sweeping equipment. Just before that, one person in each house came out for not more than half an hour and brushed all the contamination from the pavement and sidepaths into the street gutter. Following on the road sweepers which swept the fall-out into the street gutters, a water tank and pump enabled the contamination to be washed along the gutter and down the drain. It is interesting to note that in one of the American Operational Research reports the range of effort covered is one operator per 100 of the population up to one per thousand. The U.S. report - Radiological Recovery of Fixed Military Installations - gives some figures about rates of cleaning up. They assumed motorised flushing equipment, graders which scrape the earth into a windrow pile and leave it at the side, scrapers which lift up this windrow and put it into a container so that it can be moved and dumped somewhere else. They used bull-dozers, ploughs, and so on. They give the rate for fire hosing a street as 6,000 gallons per hour at 80 p.s.i. through each of two 1½ inch hoses and four men to each hose, or 7,500 sq. ft. per hour per hose. In the case of motorised equipment, i.e. the water flushing machine with two very powerful nozzles in front - this delivered 50,000 gallons per hour at 90 p.s.i. employing two men and decontaminating some 35,000 sq. ft. per hour. In the Plumbbob report the calculations were something of the same order - an unpaved area of 500 ft. X 500 ft. = 250,000 sq. ft., was decontaminated in three hours or 80,000 sq ft. clean up per hour. In my case I estimated the rate of street cleaning with a road sweeper and firehosing at between 40,000 and 150,000 sq. ft. per hour, assuming that contamination is washed down into street drains.

Now let me come to the Stanford Research Institute's study. They worked out what is called a 'methodology' for assessing the value of a decontamination procedure. Unfortunately they used a complicated basis of assessment, first a 'performance' value which is the rate of coverage multiplied by the fractional reduction of radiation divided by the exposure factor. From this they worked out a 'decontamination' value, which is the performance value multiplied by the fraction of open field radiation penetrating a shelter divided by above-ground area per capita. The results work out very much in the same range as we calculated. Two cases are assumed (a) 1 operator per 100 of the population, and (2) 1 operator per 1,000 of the population. The bulk of the effort is done by mechanised equipment but the population are expected to do a bit of spade work on unpaved areas. In the paper they give very interesting data on the distribution of certain types of surface in American towns and the proportion of certain classes of people likely to be available and useful for undertaking the decontamination. Assuming one operator per hundred of the population, a 50% dose rate reduction could be achieved if each member of the crew worked two 10-hour shifts, and a 90% dose rate reduction if each worked twenty 10-hour shifts. In my assessment I took only 25r as the limit of exposure for people engaged on decontamination. I must now go back and do it again for a wartime emergency exposure of 75r if this is justified to enable the community to survive. I might add that this particular SRI report - if anybody is interested enough to read it - has a beautiful graph. It shows the cost of saving the United States of

America in relation to the actual cost of the protective decontamination programme, in terms of the surviving population.

It is interesting to note that in an average American town, per 1,000 inhabitants there are 0.7 Sanitary Department employees, one fireman, 2.9 highway department workers, 1.4 policemen. These with watchmen and cleaners make up 1.8% of the total population possibly able and available to do this job. They have also considered that in America, of course, all cars would have their tanks at least half full in emergency - that means something like 10 hours travelling at 25 miles an hour, so everybody could beat it out of the contaminated area for some 250 miles. Each would have to take his own food, and this is where the Stanford Institute's estimate stops. They say they can carry the operation no further because they do not know what would happen when the family food supplies ran out.

I would like now to refer to the extremely valuable factual report on Operation Plumbbob in 1957. The report is called the 'Evaluation of Countermeasure System Components and Operational Procedures', but I don't think one ought to let the title frighten us away from the value of the report. They built an underground magazine type shelter about 25 ft. in the middle by 48 ft. long, covered with 3 ft. of earth, and they carried out a study of the dose rates during gamma flash and residual effects inside and outside the shelter to several days after the burst. It had large ventilators and one of the objects was to study the internal dose at various points inside in relation to the various apertures of the shelter. In the second part of the programme - three areas outside were selected as likely to receive fall-out. In one of the shots this particular shelter was almost a mile from Ground Zero. After the shot the fall-out built up over the shelter very rapidly - it started in about six minutes and it reached a maximum in 15 minutes from the burst. The maximum was 60 r.p.h., which is higher than they had budgeted for. It had been intended that a party should come out from the shelter to monitor the areas and to decontaminate one of the selected areas seven hours after the shot, but in an area at 60 r.p.h. at 15 minutes after burst, this was not possible until two days after and it presented a very valuable opportunity as the area was thoroughly monitored before and after decontamination and all personnel carried film badges. Three areas had been marked out, and at 7 hours after burst monitors were sent out to measure the dose rate at the centres of the three areas. One area which had a fairly high dose rate of 3 r.p.h. at 7 hours was selected. The area was a square of 500 ft. side. Two days after the burst four monitors went out and started at the centre and proceeded in steps to each corner, and the whole area was very thoroughly monitored at heights above the ground of 1 ft., 2 ft. and 3 ft. Another monitor went to various points outside and measured the dose rates so that we have a complete record of all relevant dose rates before, during and after the decontamination operation. The crews and their equipment consisting of four motor graders (pushing the earth to the side into windrows), two motorised scrapers, and one bull-dozer was kept three miles from G.Z. in a clear area. Decontamination was done in four stages and took three hours. In the first stage an area of 40 ft. X 40 ft. was cleared and then an additional 20 ft. round the periphery. This was then extended to 100 ft. X 100 ft. and finally to 500 ft. X 500 ft. The central area of 100 ft. X 100 ft. was monitored and rescraped in an attempt to get down to a residual number (R.N.) of 0.01, i.e. 99% dose rate reduction at the centre. However this was not achieved. The results at 3 ft. height were:-

Area	R.N. at Centre (average)
40ft. X 40ft.	0.39
60ft. X 60ft.	0.32
100ft. X 100ft.	0.24
500ft. X 500ft.	0.16

A second pass over the 100 ft. X 100 ft. area gave an R.N. of 0.11. The ground was rough and hard and a lot of boulders had to be removed which slowed

them down very considerably. They also measured the dose which was obtained by the crews doing the job, but gave no record of the dose received by those who did the monitoring. The dose rate to the crew in the mechanised equipment amount to 175 m.r. when theoretically they should have got 820 m.r., i.e. a reduction to 1/5th corresponding to an average protective factor of 5 while they were engaged on this work. Another area of 100 ft. X 100 ft. was decontamined, but instead of a 200 ft. wide cleared buffer zone this was surrounded by a 3 ft. high peripheral barrier of earth. The operation took a total of 1.3 hours and gave a residual number of 0.16, so that the 3 ft. earth barrier all round the area was equivalent to the 200 buffer zone round the 100 ft. X 100 ft. area in the previous case.

XVI MR. G WORTLEY presented a paper, which had been circulated before the meeting, entitled The Effect of Nuclear Weapon attack on Food and Food Production.

XVII BRIGADIER J. A. MULLINGTON described A Proposed Food Monitoring Organization and a summary of his remarks had also been circulated.

DR. PURCELL. We go on to the subject which I hope you agree with me is important, as to how the food monitoring service should be organised, and any general discussion you wish to have regarding the technical side of the two addresses that we listened to this morning. We still have the representatives of the Ministry of Agriculture, Fisheries and Food here to help us and to answer questions. I would like to know whether you do consider it feasible for the S.I.O's to undertake the additional duties of food monitoring.

PROFESSOR BRADLEY: The alternative would be to have two separate organisations?

BRIGADIER MULLINGTON: Summarising the position at Region, the proposal is that there should be separate advisers for food, but working in co-operation with you; and we hope to have your advice and comment on personalities and on the organisation.

DR. PURCELL: At Divisional level I don't think you really need our help except on the organisation side, on the question of how all this works in with operational planning and procedure. As a Central Government responsibility food supply will presumably come under the Regional Commissioner's control and must be tied in with the rest of his organisation.

Coming down to Area level, there it is suggested by Brigadier Mullington that the people needed for food monitoring should be S.I.O's rather than a new set of people recruited and organised quite independently. The question of training those people has been given a little initial thought. It was felt that this was a specialised task and as I understand it the M.A.F.F. are prepared to accept a great deal of that responsibility.

COLONEL BATCHELOR. Can we get any sort of idea of the possible length of specialist training required for the S.I.O's at Area level; would it be days or weeks or hours.

MR. WORTLEY: We think about two days.

MR. MARTIN: I believe Colonel Batchelor may have had in mind the thought that we might be responsible for this training, but I think this is not the view of the Ministry of Food, who conceive that if the S.I.O's are nominated who are willing to undertake what is probably after all a relatively small additional duty, then their training would be given centrally by the M.A.F.F. Whether centrally or regionally, that is a matter for the M.A.F.F.

A SPEAKER. I am not quite clear what the S.I.O. is expected to do in this. I think it is something more than the most we have yet heard.

BRIGADIER MULLINGTON: We envisage him as being an adviser on food ingestion problems - what food can be eaten.

MR. WORTLEY: He would be expected to have a preview of available food resources, and have a plan as to how he would tackle the job of assessing the supplies in his area. He would be expected to say what food hazard can be accepted, and we envisage that the Medical Officer of Health would rely very heavily on him for advice.

PROFESSOR BLACK: The more one hears of this the more it seems to be an extra burden on the S.I.O. taking him away from the job for which he has hitherto been trained. Rightly or wrongly 90 per cent of the S.I.O's are more on the physical side, and I think it is possible that selection will be advisable. Those people who are biologically minded might be able to be trained fairly quickly up to the required standard. On another point, the question of exercising these people is going to be very difficult, and it is vitally important. As I understand it the main use of the S.I.O. in this work is going to be after some days, probably after the first week, and no exercise has yet been run for so late a period. We have not really begun to tackle the situation in its later stages on an exercise basis.

PROFESSOR GARNER: I do not think a man can serve two masters or should try to do so. I feel that as a point of organisation it is unsound.

DR. PURCELL: But he is serving one master. There will be no demands on him in peace.

PROFESSOR GARNER: No I think he is serving two masters, because his thoughts even in peacetime will have to be given to this rather vital problem of monitoring food. I feel that you should have two parallel services. Those concerned with food should be definitely under the M.A.F.F. but associated with the S.I.O's, on account of the smallness in numbers, for Civil Defence purposes.

DR. PURCELL: We are talking about D + 7. As Professor Black has pointed out we do not know how many S.I.O's we really need to deal with the situation from that time onwards, because no one has had the ability or foresight to realise visually the situation following a realistic attack in any detail. Equally the Ministry of Food, when they gave a figure of 370, were giving what Brigadier Mullington considered should be the initial bite at this cherry, and not the number that he would really need in war. I believe that on our side of the house we may well find that we can use any trained or semi- trained individuals to any numbers once they are available, and no doubt Brigadier Mullington is thinking that probably for him the same applies. If then we are going to divide them and try to reach realistic numbers in these services, shall we not reach a point where we are cutting one another's throats and neither of us will get the numbers we want.

PROFESSOR GARNER: I quite agree to use the S.I.O's for both purposes. It is only the question of organisation. In the Sub-Regions we have trained five or six S.I.O's for the M.A.F.F., and they could be recruited, but it would take them out of the Controller's team.

PROFESSOR BLACK: If they are going to use part of the S.I.O. team, I think we might well have some S.I.O's who have been trained as biologists in the background as well as those trained on the physical side. They would be particularly responsible for the health side, and when our phase of the battle was over they might take the leadership on the other side. The essential thing would be one's actual personal knowledge of personalities in the team, for it is quite clear that some of our S.I.O's are better than the others and some of them are more reliable than others, and this will be known inside the team inevitably. It will be much better if these people are all really part of the same team.

DR. PURCELL: You are saying really that on the whole you agree with us that somehow one has got to do it on this basis.

DR. WARD: I think in practice it might very well turn out that the job in relation to food is far more important than any other issue, because food will be very important in these days. I think it would be desirable to keep the food S.I.O's in the general team. I agree with what has been said and would try to make the interchange possible. It may be necessary to shift people around very quickly. In a suburban district the food S.I.O. might have very little to do, but in London districts he might have something like half the food supply of the country to cope with, and it might very well be necessary to bring in reinforcements from other parts of the S.I.O. team.

DR. PURCELL: I personally would accept that. Suppose in a dock area you had got separate teams. In the event the Regional Commissioner would give orders for one side or the other to release their men, so that in fact you would either voluntarily, or by order, make them into one team.

DR. WARD: It would be very useful if something about food were included as part of the training for all S.I.O's.

DR. PURCELL: We have had a feeling that something new like this helps to maintain the interest of the S.I.O's in their work, but it would not be appropriate to put it forward in this way at this stage.

PROFESSOR BRADLEY: There is already in this country a body responsible for the inspection of food, its fitness to eat and so on. Is not this something that should be grafted on to their duties, rather than added to ours.

DR. PURCELL: The real problem that we are discussing here surely is the one of maintaining government under war conditions, and how activities such as this tie in at the various levels below the Regional Commissioner.

GENERAL IRWIN: The way I feel about it is that with the enormous lack of communication of all kinds which there will be after an attack, the whole resources of the G.P.O. and of those helping them will have to be narrowly concentrated in systems of some kind; they will not be able to spread their energy over the whole country; therefore you need a chain of control, and all activities must be tied in at some particular point on that system, so that controls can get the information they need from you and necessary instructions can be issued; so I think sticking to an established line of communication is essential. I was at first attracted by the idea that the general periods of activity of the food monitoring and the S.I.O's work would be different, that the S.I.O. would be immersed for the first few days and thereafter free at a time when the food monitoring was needed. I admit that there is a lack of information. We do not really know, as you have said, what the situation will be after a week. I would have thought that a country which had been subjected to a heavy attack would have residual problems which would keep the S.I.O's still very busy indeed.

DR. PURCELL. It is a very difficult problem. In the first place you would have to allocate priorities, and it would seem that food at D + 7 would be a very high priority, and consequently whichever way you look at it it seems to me that the method we are proposing is still the reasonable way of tackling the job.

GENERAL IRWIN: It looks realistically that if you have all your S.I.O's trained in all these jobs, not only their main duty but food as well, you have an organisation which is elastic and can be applied to whatever task is needed. At the same time the M.A.F.F. despite the fact that we are all serving one master, need to be assured that they can rely at all times on a body of men over whom they have some control. To start off with some S.I.O's who are experts in this field is a good thing; they at least will be competent for the job. If at a later stage you find the whole body of the S.I.O's can become more versatile in all their tasks, so much the better.

CAPTAIN McCREIGHT: What is the tie up between the Water Authorities and Food. Would the same people be able to monitor water and food?

DR. PURCELL: At present we are under no pressure to provide water monitoring. I believe that is the responsibility of the Ministry of Housing and Local Government, and I think their arrangements are made independently through the actual waterworks people.

CAPTAIN MCCREIGHT: Would there not have to be quite a lot of local monitoring of water from wells etc.

DR. PURCELL: Not in the essential stage I think. In fact we are relying on underground water as one of our main reserves, and any well that is acceptable under normal health standards could I think also be accepted for this hazard.

PROFESSOR HUNTER: I should like to separate the two jobs of monitoring and food advice. These are two entirely different things and require entirely different experience. Monitoring could be done by any S.I.O. but not advice.

BRIGADIER MULLINGTON: Could they not say if a certain food is acceptable.

PROFESSOR HUNTER: I don't think so. For instance if you are monitoring grain, who but a food expect can say whether that grain when made into bread would be suitable, because it depends on the weight of bread eaten per head and on all sorts of other factors, food habits etc. I think it is much deeper than the ordinary experience of the S.I.O.

DR. PURCELL: If the S.I.O. plus the Food Officer would not be capable of tackling it, quite honestly I don't see how it is ever going to be tackled.

PROFESSOR HUNTER: There are such people as nutritionists - why not use them.

PROFESSOR BLACK: I think the position is the other way around. If these nutritionists are available let them do an S.I.O. training.

PROFESSOR HUNTER: I think that is the way I would like to see it done. We ought to have one on every Controller's staff.

DR. PURCELL: That is attractive in some ways, but again if you consult General Irwin he will I am sure tell you that the number of places available in a control under war conditions do really not allow a multiplication of staff in this way. I would have thought that the whole organisation would become too complicated, rather like a minor Civil Service. Decisions would have to be taken quickly and often on approximate information.

BRIGADIER MULLINGTON: I can see no monitoring happening until after the first four or five days and indeed in the worst zone there would be no monitoring for quite a long time. Then I see a stage of simple monitoring, and segregation, that is - if a supply doesn't look very good and its reading is high, leave it on one side for the activity to decay. A third stage is the detailed examination of this material and by that time I believe a number of the S.I.O's should be free from their normal duties.

MR. MARTIN: The idea seems to be to have, as part of the Regional Scientific team, a Scientific Adviser on Food who will work in close contact with our own Advisers for Civil Defence. Now what kind of man is wanted for this food function? Mullington has said that he will be seeking your advice about suitable people in the Regions. What kind of people are we looking for? Is it for example a professor of Biochemistry in the local University, or is it someone else.

PROFESSOR HUNTER: I should say it is a professor of Nutrition. We have several. It is certainly not a Professor of Chemistry or Physics. Biochemistry is concerned; biology is concerned. The closer you get to the food side the better.

PROFESSOR GARNER: Have the Regional Directors been informed of this scheme, because they would be able to advise on points of organisation.

DR. PURCELL: What sort of advice are you thinking of.

PROFESSOR GARNER: I suppose there will be a Regional Commissioner, but I am not quite sure how the Regional Director stands in respect to him. Will the Regional Director still be on the Civil Defence side and the Regional Commissioner have control of a wider range.

DR. PURCELL: I would imagine that the Regional Director would in a number of cases at least be the Staff Officer under the Regional Commissioner.

GENERAL IRWIN: Yes, he would be the Regional Commissioners adviser on Civil Defence matters so called, but not over the whole field. He is in line with the Regional Police Commander who advises on police matters, and the Fire Commander on all fire matters. But alongside the Regional Commissioner there is what they call the Principal Officer who is the Regional Commissioners' right-hand man over the whole field of senior Civil Servants.

PROFESSOR GARNER: There must be a chain of command all the way down the scale to the S.I.O.

PROFESSOR EMELEUS: Is it not desirable, whatever the organisation may be, that as many S.I.O's as possible should know what the true problems are and be trained to handle them. From what I have heard of this problem it requires the use of biologists.

PROFESSOR HUNTER: May I put another point of view. On the decision of this man may depend the lives of hundreds of thousands of people, and I think he ought to be as well qualified as possible to give proper advice, and I would suggest that you take steps to recruit food specialists.

DR. PURCELL: We are considering this view. I believe your really specialised work has got to be done beforehand and worked out in operational orders. But we should be delighted if we could see a practical way of really interesting all these people and getting their help, because nobody wishes to use less qualified people if more highly qualified ones are available.

COLONEL BATCHELOR. If a food S.I.O. at an Area Control found himself faced with a situation for which his training did not qualify him, surely he would have a chain of communication up to the recognised food expert at Sub-Region or Region.

DR. PURCELL. With the Ministry of Food, control would be at as high a level as possible in order to guard against mistakes. In such a case I do not think it is a problem for a nutritional expert but for a man with a broad scientific training.

DR. WARD: Quite apart from the radiological hazard you have still got the problem of making sure the food is not bad in the conventional way.

PROFESSOR BLACK: One point about Region. In the planning it is very important to think whether the task at Region will start earlier or later than the task at Area. On the whole I would think the task at Region would develop more slowly. Thought should be given as to whether the food scientist at Region is going to be primarily a M.A.F.F. man in the Food Office, and if in fact, supposing no scientific task develops for a week, he will be occupying valuable space and eating food which may be wanted elsewhere. Should we not put the Food Scientist into the scientific room and use him for the first few days on scientific work under the Regional Scientific Adviser, knowing that as the food situation develops he will be fully in the picture, and can then go over to food.

DR. PURCELL: That is really what we have in mind, that during the initial period he will be working as a normal member of the team, so that you keep a balance among the people required. Whatever may be the requirements in the later period, the big demand on rescue will be in the first few days of the life-saving period, when you have got to do things quickly. Once fall-out is down and contours outlined, at least you have accumulated some of your basic data. You can lay down your public control conditions. It will not be very much good Brigadier Mullington

wanting to go into the middle of a Z zone for the food there until considerably later, and it does look on a first analysis as though his tasks will develop im a fairly orderly way.

BRIGADIER MULLINGTON: I see him starting fairly early. The Regional Food Controller will be edging round to see where he can get food from for areas badly hit.

DR. PURCELL: Well I quite agree with that, but I am equally convinced that his movements will be limited by the public control conditions and the gradual clearance of the zones. Could I ask you to continue to turn this problem over in your minds and let me have any considered opinions that you may have by correspondence; that is the best conclusion for this afternoon.

III MR. STANBURY gave a talk on Study Torquemada, dealing with Fire Problems after a Megaton Explosion. He has provided the following summary:-

I. Estimation of initial fire incidence

The method used is based on that described in the Report of the Technical and Tactical Study Courses held at the Fire Service College in May, June and July 1952 entitled "The Fire Situation after an Atomic Attack on a British City" - a copy of which can be made available on application.

The British city concerned in these particular study courses was Birmingham and for this purpose a 1 in 12 scale model was made by the Birmingham Fire Brigade covering a 25° sector of the area likely to be affected by the explosion of a nominal atomic bomb over the centre of the city. With this model the problem of shielding - which is all important in this connection - could be dealt with quite satisfactorily. A lamp was set up at the point of burst in relation to the model, and it could be seen immediately which windows were exposed and which were shielded. After that it was only a question of estimating the chances of the development of continuing fires in relation to the fire risk and size of the fire compartment concerned by the methods described in detail in the report.

In this study we were concerned with the much larger area of damage produced by a 1 MT explosion, and we had no model. We are forced therefore to use maps and the most detailed maps available were the Insurance Plans of Liverpool and Birkenhead prepared by Messrs. C. E. Goad Ltd., which were hired specially for the purpose. These are to the scale of 40 ft. to the inch and they give complete details about road widths, height of buildings, construction etc. In order to reduce the volume and tediousness of the work involved in using maps the method developed for the Birmingham model had to be substantially simplified.

Effect of Shielding: Estimation of the Number of Exposed Floors

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height, then the number of exposed floors on the front of the buildings on the side of the road away from the explosion depends on

(a) the angle of arrival of the rays, say α and

(b) the width of the street = 10w

Where w = number of units of 10 ft.

If we take the average depth of a floor to be 10 ft. then the number of exposed floors is given by

$$\tan \alpha = \frac{10n}{10w} \quad \text{or } n = w \tan \alpha$$

For a 1 MT groundburst bomb the height of the top of the fireball above ground is about 0.72 miles. Because this distance is large compared with the height of most buildings, the exposed upper floors do actually see a large part of the fireball and not just the top of it, but in assuming that the radiation is just as intense from the top as from the middle we are probably overestimating the fire situation which will result.

On the above basis the following table gives the number of exposed upper floors (to the nearest ½ floor) for a range of distances from the explosion and a range of street widths.

TABLE I

Distance from explosion miles	Angle of arrival α^o	$\tan\alpha$	Width of street (units of 10 ft.)						
			2	3	4	5	6	7	8
1	35	.72	1.5	2	3	3.5	4.5	5	6
1½	26	.48	1	1.5	2	2.5	3	3.5	4
2	20	.36	.5	1	1.5	2	2	2.5	3
3	13½	.24	.5	.5	1	1	1.5	1.5	2
4	10	.18	.5	.5	.5	1	1	1.5	1.5
5	8	.15	.5	.5	.5	.5	1	1	1
6	7	.12	-	.5	.5	.5	.5	1	1
7	6	.1	-	-	.5	.5	.5	.5	1

It is obvious that for street widths greater than 80 ft. at close ranges (or for example where there is an open space in front of a building) it can be immediately assumed that all floors are exposed; since few buildings have more than 5 or 6 floors. At the extreme range for ignition the angle of arrival varies so slowly that for street widths greater than 80 ft. the number of exposed floors can always be taken as one. It is for these reasons that the Table is stopped at 80 ft.

To the numbers obtained from Table I must be added or subtracted the differences in numbers of floors of opposing buildings as shown on the maps to give the actual number of exposed floors in any particular case. This number of course cannot be negative, nor greater than the total number of floors in the building exposed.

Variation with Range

In the Birmingham study an attempt was made to allow for the variation in intensity of the radiation, with distance from the explosion on the chance of ignition, but the foundation for this was not very sound. In this study it was assumed -

(a) that there are no continuing fires inside a circle 1 mile in radius because of the complete collapse of all buildings

(b) that out to 1½ miles the only fires possible are those in buildings of steel framed or reinforced concrete construction

(c) that the chance of ignition is 100% all the way from 1½ miles to 5 miles, after which it drops to 30% for a further 2 miles. [At 7 miles from a 1 MT explosion the heat intensity is still 12 cal/sq.cm which is sufficient to ignite easily inflammable material like "Excelsior".]

Inclination of Streets to the Direct Line of the Heat Flash

The first two lines of the following table are taken from the Report already referred to.

TABLE II

Angle between heat flash and street (degrees)	90-75	75-60	60-45	45-30	30-15	15-0
Proportion of heat flash entering windows %	99	92.5	80	60	40	14
Proposed grouping for Torquemada	100%		80%		Nil	

For working with Goad Maps, the division into 6 angular groups is too cumbersome, and it was decided to use the 3 group system shown in the last line. This means that all streets inclined at an angle greater than 60° to the direction of the flash are assumed to be at right angles to it; all those between 30° and 60° have their chances of ignition reduced by 20%; and those below 30° are neglected. A small pilot study of one area showed that this approximation was very close, while the saving in work was considerable.

The chance of a continuing fire as affected by (a) Size of Fire Compartment and (b) Number of Windows.

This was dealt with in great detail in the earlier report, but considerable simplification was needed for use with the Goad maps.

The chance of a continuing fire developing from a small source of ignition decreases with the size of the fire compartment and increases with the number of sources of ignition i.e. with the number of exposed windows, and these were dealt with separately in the Birmingham model assessment. However, the decrease with size is roughly proportional to the area and the increase - because of windows - to the length (assuming an approximately square building). The overall effect is that the chance is inversely proportional to the length of the exposed front of the building.

In this study the chance has been still further reduced by two assumptions

(a) that 25% of the windows have been whitewashed and

(b) that 25% of the incipient fires are extinguished by fire guards giving an overall reduction of the chance of fire of 55% (75% x 75%).

Owing to the uncertainly connected with this part of the estimation there seemed to be no point in using more than 3 main fire compartment size groups and the figures finally adopted were as follows:-

Group (A) 20 ft. frontage. Chance 0.2

Group (B) 40 ft. " " 0.1

Group (C) 80 ft. " " 0.05

In the streets inclined between 60° to 30° to the heat flash, these chances were reduced by 20% to

Group (A)	0.16
Group (B)	0.08
Group (C)	0.04

The Method of Estimation

The following routine method was adopted for making use of the principles enumerated above.

1. For any particular sheet of the Goad maps, the distance of the centre of the street to ground zero was first estimated to the nearest mile.

2. From the N/S pointer on the sheet, the direction of the flash was determined and the streets perpendicular to this (within 30°) were noted.

3. Starting from one end of each street, each exposed fire compartment was considered in turn and the number of exposed floors marked on a tracing paper overlay, using Table I together with the information on the numbers of floors of opposite buildings given on the map.

4. All the fire compartments in Group (A) were then noted and the number of exposed floors for each was multiplied by the chance of a continuing fire developing (0.2 in this case) and the number recorded on the overlay in Green. The fire compartments in Group (B) were dealt with in a similar way and the number recorded on the overlay in Yellow. Finally the fire compartments in Group (C) were dealt with, and the chances recorded on the overlay in Red.

5. This process was repeated for the buildings in the streets inclined between 60° to 30° to the flash, but using the appropriately reduced chance figures.

6. All the figures in each of the colour groups were then added to give the total chance that continuing fires would be started on any one floor of any one building for each group of fire compartment sizes. Let us assume that these numbers are x, y and z. Then these numbers of fires were marked in on the overlay as red ticks, the actual choice of which building in each group being immaterial.

Inevitably there were many classes of buildings which did not respond readily to the above method of analysis, and each had to be considered on its merits, bringing into play as much wartime experience in this field as was available to the Branch.

Secondary fires

The problem of so-called "secondary" fires i.e. - those started as a result of disruption of some kind or another caused by the blast - was dealt with in great detail in a paper entitled "The Fire Risk from Blast Damage" which also appeared in the Fire Service College Report already referred to. This was based on a careful study of all the fly bomb records. It was found that about 6% of the bombs were responsible for large continuing fires and about 40% for small fires in debris most of which went out of their own accord. If we assume that one tenth of the small fires continue the overall figure for continuing fires is 10%. In a groundburst 20 KT bomb, the damage produced is equivalent to that of about 1,250 fly bombs. For a 1 MT groundburst the number would be -

$$1{,}250 \ \frac{(10^3)}{(20)} \ \cdot \ ^2/_3 \ = \ 50{,}000$$

and if 10% of these cause fires, there will be 5,000 secondary fires.

It is not expected that this type of fire would occur beyond six miles since this is the limit of damage. Thus secondary fires might occur on the average at a ~~desnity~~ density of $\frac{5000}{\pi 6^2}$ = 40/sq. mile.

Each Goad Map covers an area of approximately 1/40th sq. mile so that on each map one extra fire must be included. Here again it is not important where fire is located, but it is reasonable to select a high fire risk occupancy such as paint ~~sotre~~ store, a furniture factory, or a garage.

II. Estimation of Fire Spread

In the area of Liverpool and Birkenhead covered by the Goad Maps, the numbers of fires at H + 1 turned out to be as follows:-

Fire Compartment Size	Number
Small	1050
Medium	223
Large	20
	1293
Secondary fires allocated in roughly the same proportion	180
	1473

The area not covered by the Goad Maps was largely residential so that most of these additional fires were in the small compartment category.

The total number of fires was between 7,000 and 8,000, and it was decided to allocate the following round numbers to each category:-

Small (S)	7,000
Medium (M)	500
Large (L)	50
Total (N)	7,550

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs; thus the assumptions adopted must allow for the final destruction by fire of about 15,000 buildings which is about 1 in 10 to 1 in 15 of all the buildings in the area.

For the purpose of assessing possible spread let us assume -

Proportion of fires in each category which burn out without spreading $= p_1$

Proportion of fires which spread to one other building $= p_2$

" " " " " " two " buildings $= p_3$

" " " " " " three " " $= p_4$

In each category $p_1 + p_2 + p_3 + 4 = 1$ and the final number of buildings destroyed by fire =

$$S(p_1 + 2p_2 + 3p_3 + 4p_4)s$$
$$+ M(p_1 + 2p_2 + 3p_3 + 4p_4)m + L(p_1 + 2p_2 + 3p_3 + 4p_4)l$$

As a first shot the following numbers are suggested:-

	Fire Compartment Size		
	Small	Medium	Large
p_1	.6	.25	.1
p_2	.2	.25	.2
p_3	.1	.25	.3
p_4	.1	.25	.4

This gives:-

Final number of buildings destroyed by fire = (7,000 x 1.7) + (500 x 2.5) + (50 x 3.0) = 13,300 which is near enough for this purpose.

In order to estimate the number of fires burning at any given time it was necessary to make further assumptions about

(a) burn-out times and

(b) starting times for first, second and third spread fires.

The following are suggested:-

	Fire Compartment Size		
	Small	Medium	Large
Burn-out time from ignition (hours)	$1\frac{3}{4}$	$3\frac{1}{2}$	7
Starting time for			
1st-spread fires	H + $1\frac{1}{2}$	H + $1\frac{1}{2}$	H + $1\frac{1}{2}$
2nd- " "	H + 3	H + 3	H + 3
3rd- " "	H + $4\frac{1}{2}$	H + $4\frac{1}{2}$	H + $4\frac{1}{2}$

These two sets of assumptions, combined with the actual numbers of fires in each category were then used to calculate the fire position at various times after H + 1 as follows:-

Time After Burst (hours)	Origination of Fire	Fire Compartment Size					
		Small		Medium		Large	
H + 1	Initial heat flash + secondary fires	7,000		500		50	
H + 2	Initial fires	Nil	2,800	500	875	50	95
	1st spread fires (p2 + p3 + p4)	2,800		375		45	
	2nd " " (p3 + p4)	Nil		Nil		Nil	
	3rd " " (p4)	Nil		Nil		Nil	
H + 4	Initial fires	Nil	1,400	Nil	625	50	130
	1st spread fires (p2 + p3 + p4)	Nil		375		45	
	2nd " " (p3 + p4)	1,400		250		35	
	3rd " " (p4)	Nil		Nil		Nil	
H + 8	Initial fires	Nil	Nil	Nil	125	Nil	100
	1st apread fires (p2 + p3 + p4)	Nil		Nil		45	
	2nd " " (p3 + p4)	Nil		Nil		35	
	3rd " " (p4)	Nil		125		20	

These numbers were divided between the various fire areas in the Liverpool-Bootle district using the H + 1 assessment as the basis. The local fire officers with their special experience of the fire risks in their areas, allocated the positions and determined where the fire spread was most likely to take place. This work, which was most painstakingly carried out resulted in the production of the four fire situation maps which you see here displayed.

XIX DR. PURCELL: I should like to say how much we have appreciated the help of the Scientific Advisers during the past year. Additionally I know that you will not wish to close without allowing me to say to the Commandant of the Staff College how much we appreciate the kindness and hospitality that we have received during this Conference. We particularly appreciate his magical touch with the weather; the sun always shines when we come here. Thank you very much indeed.